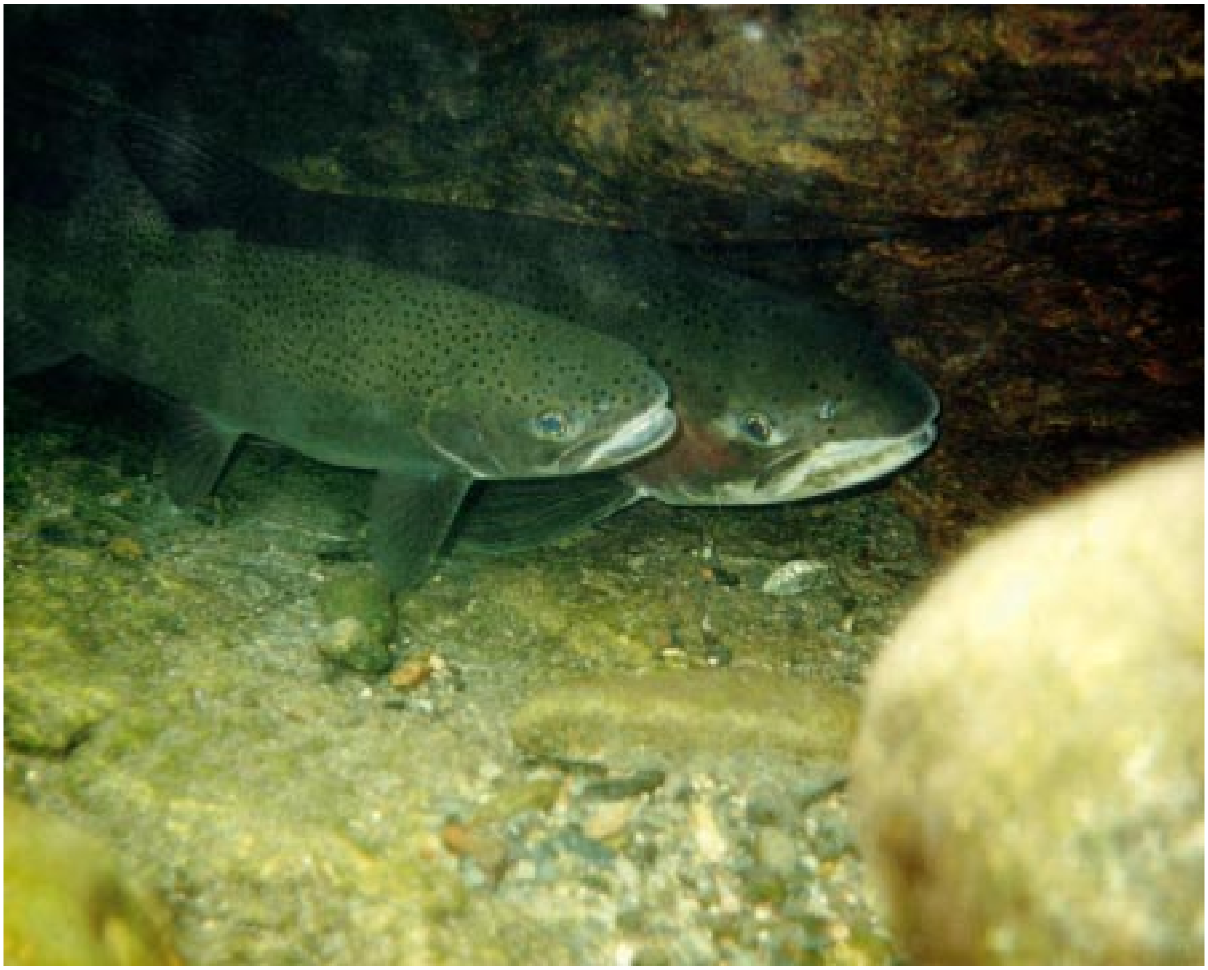


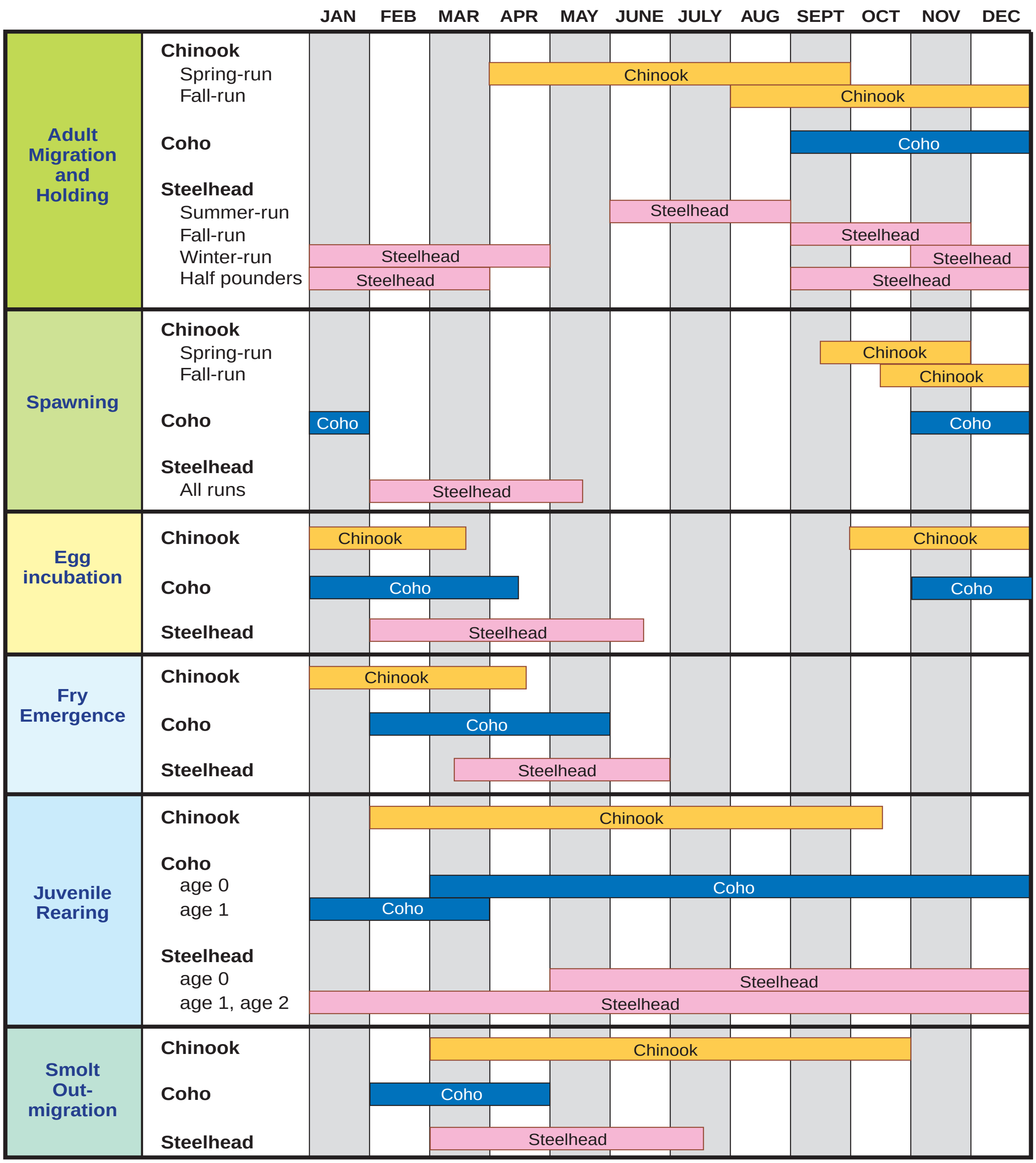
CHAPTER 3 Trinity River Fish and Wildlife Background

3.1 Fish Resources

Commercial, Tribal, and sport fisheries depend on healthy populations of steelhead (*Oncorhynchus mykiss*), coho salmon (*O. kisutch*), and chinook salmon (*O. tshawytscha*). The following sections describe the habitat requirements and life histories of these fish species and document their decline. Any recommended measures to restore and maintain the Trinity River fishery resources must consider these life histories and habitat requirements.

The life histories of anadromous species have two distinct phases, one in freshwater and the other in salt water. Newly hatched young remain in the river of their birth for months to years before migrating to the ocean to grow to their adult size. Adult salmonids return from the ocean to their natal rivers to spawn. Although steelhead, coho salmon, and chinook salmon require similar instream habitats for spawning, egg incubation, and rearing, the timing of their life history events varies (Figure 3.1). Published values

> "Commercial, Tribal, and sport fisheries depend on healthy populations of steelhead (*Oncorhynchus mykiss*), coho salmon (*O. kisutch*), and chinook salmon (*O. tshawytscha*)."



* A small percentage of chinook in the Trinity River overwinter and outmigrate at age 1, similar to coho age 1 life history.

Figure 3.1. Diagram of the timing and duration of various life-history events for chinook salmon, coho salmon, and steelhead in the Trinity River.

for each species' life history requirements are presented in Tables 3.1 to 3.3; depth and velocity (microhabitat) requirements and temperature requirements by life stage are discussed in Sections 5.1 and 5.5.

3.1.1 General Habitat Requirements and Life Histories

Anadromous adult salmonids enter the river from the ocean and hold until they are ready to spawn. Some species, such as spring-run chinook and summer steelhead, enter the river months prior to spawning; these fish hold in deep pools for protection from predators and for cool thermal refuge during the summer. Once spawning begins, salmonids construct redds (spawning areas) in gravel. Adult salmonids select a spawning site with appropriate gravel size, water velocities, and depth (refer to Section 5.1 for species-specific data for Trinity River salmonids). The size of the gravel selected by the fish is typically related to the size of the fish constructing the redd. Adult salmonids deposit eggs into the redd where they incubate in the spaces between gravel particles. Clean spawning gravels are important because fine sediment accumulation in the redd can affect the oxygen supply to the eggs, decreasing survival and (or) emergence success (Tagart, 1984). Conversely, good subgravel flows provide high levels of dissolved oxygen, resulting in increased egg survival to hatching (Shaw and Maga, 1943; Wickett, 1954; Shelton, 1955; Shelton and Pollock, 1966; Healey, 1991). Incubation time for eggs and egg survival rates are dependent on water temperature, with warmer water supporting faster hatching times (Alderdice and Velsen, 1978). Redd scour, often associated with flooding, can increase egg mortality (Gangmark and Bakkala, 1960), but scour is necessary to maintain clean high-quality spawning gravels (McBain and Trush, 1997).

"Clean spawning gravels are important because fine sediment accumulation in the redd can affect the oxygen supply to the eggs, decreasing survival and emergence success. …scour is necessary to maintain clean high-quality spawning gravels."

After hatching, the sac fry remain within the gravel interstitial spaces for 4 to 10 weeks to avoid predation and dislodgement by high flows (Dill, 1969). After the egg sac is absorbed, the fish emerge from the gravel and are referred to as "fry" (total length < 2 in. for purposes of this report). Fry commonly occupy shallow waters with little or no velocity (refer to Section 5.1 for species-specific data for Trinity River salmonids), and use cover such as undercut banks, woody debris, overhanging vegetation, and the interstitial spaces between cobbles. Fry tend to disperse downstream with flow increases and (or) with high fry densities (Lister and Walker, 1966; Major and Mighell, 1969; Healey, 1980). Increased flows disperse fry, but extreme flow fluctuations during the emergence period can be detrimental to the year-class (Coots, 1957).

During the next life-history stage, the juvenile or "parr" stage, juveniles spend from several months to 3 years growing in freshwater, depending on the species. As fry and juveniles grow larger, habitat preferences change. Juveniles move from stream margins and begin to use deeper water areas with slightly faster water velocities (specific depths and velocities for Trinity River salmonid lifestages are presented in Section 5.1). Individual rearing

"Upon reaching a species-specific size, juvenile salmonids undergo smolting, a physiological metamorphosis that prepares them for outmigration from the river and for growth and survival in the ocean. . . . increased smolt survival may subsequently increase the numbers of returning adults."

Table 3.1. Specific parameters for chinook salmon life-history requirements from published literature.

Chinook Salmon Life History Requirements			
Spawning Requirements			Citation(s)
	Redd sizes	36 - 108 ft^2	Bjornn & Reiser 1991
	Territory sizes	144 - 216 ft^2	Burner 1951
	Gravel sizes	0.5 - 4.0 in.	Bjornn & Reiser 1991
	Velocities*	0.33 - 6.2 ft/sec 0.1 - 5.0 ft/sec	Healey 1991 Bjornn & Reiser 1991
	Depths*	0.16 - 23+ ft ≥ 0.78 ft	Healey 1991 Bjornn & Reiser 1991
	Eggs buried to depths	0.6 - 2.0 ft 0.65 - 1.4 ft	Healey 1991 Bjornn & Reiser 1991
Fry Rearing Requirements	Depths*	shallow, stream margins	Chapman & Bjornn 1969, Everest & Chapman 1972
	Velocities*	little to none	Chapman & Bjornn 1969, Everest & Chapman 1972
Juvenile Rearing Requirements	Depths*	0.5 - 4.0 ft	Bjornn & Reiser 1991
	Velocities*	0 - 3.9 ft/sec	Everest & Chapman 1972 Bjornn & Reiser 1991
	Optimal rearing temperatures**	44.6 - 57.2 ºF	Rich 1987, Bell 1991
Smolt Requirements	Optimal smolting temperatures**	< 59 ºF	Clarke et al. 1981, Pereira & Adelman 1985, Baker et al. 1995

* indicates information specific to the Trinity River is further detailed in Section 5.1.
** indicates a more detailed discussion of temperature requirements is presented in Section 5.5.

fish tend to stay within the same area (several feet) of the stream (Edmundson et al., 1968; Reimers, 1968), occupying faster flowing water during the day and moving to the slower velocity stream margins at night (Edmundson et al., 1968). Usually, chinook salmon rear in the river for only a few months. Coho salmon, however, rear for 1 year and steelhead rear in the river for 1 to 3 years; consequently both require overwinter habitats. These habitats consist of areas with clean cobbles and gravels, with low or no velocity to avoid displacement by winter storm floods.

Upon reaching a species-specific size, juvenile salmonids undergo smolting, a physiological metamorphosis that prepares them for outmigration from the river and for growth and survival in the ocean. The timing of smolting is crucial for smolt survival. Fish size, water temperature, flow, and photoperiod interactively determine the readiness to smolt (Wedemeyer et al.,

Table 3.2. Specific parameters for coho salmon life-history requirements from published literature. LWD = large woody debris.

Coho Salmon Life History Requirements			
Spawning Requirements			Citation(s)
	Redd sizes	16 - 30 ft^2	Bjornn & Reiser 1991
	Territory sizes	126 ft^2	Burner 1951
	Gravel sizes	1.5 - 5.4 in. 0.5 - 4.0 in.	Briggs 1953 Bjornn & Reiser 1991
	Velocities*	1.0 - 2.5 ft/sec	Briggs 1953
	Depths*	≥ 0.6 ft 0.33 - 0.67 ft	Bjornn & Reiser 1991 Briggs 1953
	Eggs buried to depths	0.6 - 1.3 ft	Briggs 1953
Fry Rearing Requirements	Depths*	shallow, stream margins	Hartman 1965, Allen 1969
	Velocities*	little or no velocity	Hartman 1965, Allen 1969
	Optimal rearing temperatures**	44.6 - 62.6 ºF	Brett 1952, Bell 1991
Juvenile Rearing Requirements	Depths*	> 1.0 ft	Bjornn & Reiser 1991
	Velocities*	< 1.0 ft/sec	Bjornn & Reiser 1991
	Overwintering requirements	lg. pools w/LWD, undercut margins and debris near riffle margins	Hartman 1965, Bustard & Narver 1975
	Optimal rearing temperatures**	44.6 - 62.6 ºF	Brett 1952, Bell 1991
Smolt Requirements	Optimal smolting temperatures**	44.6 - 53.6 ºF	Clarke et al. 1981, McMahon 1983

* indicates information specific to the Trinity River is further detailed in Section 5.1.
** indicates a more detailed discussion of temperature requirements is presented in Section 5.5.

1980; Hoar, 1988). If flows and habitat are managed to facilitate timely and successful smolting, increased smolt survival may subsequently increase the numbers of returning adults (Raymond, 1979).

The rate at which a smolt migrates out of the river is related to smolt size, flows, temperature, and photoperiod (Hoar, 1988). Increasing streamflows and increasing water temperatures tend to increase the rate of smolt migration. The rate of smolt movement also increases from early in the season to late in the season as temperatures rise and photoperiod lengthens (Raymond, 1968; Cramer and Lichatowich, 1978).

Table 3.3. Specific parameters for steelhead life-history requirements from published literature.

Steelhead Life History Requirements			
Spawning Requirements			Citation(s)
	Redd sizes	47 - 58 ft^2	Bjornn & Reiser 1991
	Gravel sizes	0.25 - 5.0 in.	Barnhart 1986
	Velocities*	0.75 - 5.1 ft/sec	Barnhart 1986
	Depths*	0.3 - 5.0 ft	Barnhart 1986
	Eggs buried to depths	8 - 12 in.	Bjornn & Reiser 1991
Fry Rearing Requirements	Depths*	shallow, stream margins; 0.25 - 1.2 ft	Hartman 1965 Barnhart 1986
	Velocities*	little or no velocity	Hartman 1965
	Optimal rearing temperatures**	50 - 64.4 ºF	Hokanson et al. 1977, Bell 1991
Juvenile Rearing Requirements	Depths*	< 0.5 - 2.5 ft 0.8 - 1.6 ft	Bugert & Bjornn 1991 Barnhart 1986
	Velocities*	< 0.05 - 1.0 ft/sec	Bugert & Bjornn 1991
	Overwintering requirements	boulder-rubble stream margins ~ 1.0 ft deep, low velocity	Everest & Sedell 1983
	Optimal rearing temperatures**	50 - 64.4 ºF	Hokanson et al. 1977, Bell 1991
Smolt Requirements	Optimal smolting temperatures**	< 55.4 ºF	Kerstetter & Keeler 1976, Zaugg 1981

* indicates information specific to the Trinity River is further detailed in Section 5.1.
** indicates a more detailed discussion of temperature requirements is presented in Section 5.5.

Depending on species, adults typically return to their natal streams to spawn at 3 to 6 years of age. Some salmon return at 2 years of age and are referred to as "jacks" (Leidy and Leidy, 1984). Although jacks are capable of spawning, most are male and do not contribute to the production potential of the spawning escapement. Steelhead, unlike salmon, do not always die after spawning, and may make three to four spawning migrations (Barnhart, 1986; Leidy and Leidy, 1984).

Each salmonid species requires slightly different microhabitats for each life stage and similar microhabitats are used by different species at different times of the year. This segregation of timing and microhabitats reduces competition between species (Bjornn and Reiser, 1991). The life histories of each species (Figure 3.1) are outlined below, with descriptions of the habitat components and lifestage timing critical to the growth and survival of each species.

3.1.1.1 Chinook Salmon

Chinook salmon are the largest Pacific salmon (Moyle, 1976). Trinity River chinook salmon populations are composed of two races, spring-run and fall-run (Leidy and Leidy, 1984). Spring-run chinook salmon ascend the river from April through September, with most fish arriving at the reach below Lewiston (RM 111.9) by the end of July. These fish remain in deep pools until the onset of the spawning season, which typically begins the third week of September, peaks in October, and continues through November (CDFG,1992a, 1992b, 1994a, 1995, 1996a, 1996b). The fall-run chinook salmon migration begins in August and continues into December (CDFG, 1992a, 1992b, 1994a, 1995). Fall-run chinook salmon begin spawning in mid-October, activity peaks in November, and continues through December. The first spawning activity usually occurs just downstream from Lewiston Dam. As the spawning season progresses into November, spawning extends downstream as far as the Hoopa Valley (USFWS, 1988, 1989,1990, 1991; HVT, 1996).

> "Each salmonid species requires slightly different microhabitats for each life stage and similar microhabitats are used by different species at different times of the year. This segregation of timing and microhabitats reduces competition between species."

Emergence of spring- and fall-run chinook salmon fry begins in December and continues into mid-April (Leidy and Leidy, 1984). Juvenile chinook salmon typically leave the Basin (outmigrate) after a few months of growth in the Trinity River. Outmigration from the upper river, as indicated by monitoring near Junction City (RM 79), begins in March and peaks in early May, ending by late May or early June (Glase, 1994a). Outmigration from the lower Trinity River, as indicated by monitoring near Willow Creek (RM 24), peaks in May and June, and continues through the fall (USFWS, 1998).

3.1.1.2 Coho Salmon

Coho salmon migrate up the Trinity River and Klamath River from mid-September through January and spawn from November through January (Leidy and Leidy, 1984). Emergence of coho salmon fry in the Trinity River begins as early as late February and continues through March (Glase, 1994a; USFWS, 1998).

After their emergence from the gravel, fry use cobbles or boulders for cover and typically defend a territory (Allen, 1969). Suitable territories may be extremely important for coho salmon juveniles, as Larkin (1977) found that the abundance of coho salmon may be limited by the availability of these appropriate habitats.

In the summer, coho salmon parr reside in pools and near instream cover, such as large woody debris, overhanging vegetation, and undercut banks (Sandercock, 1991). Overwintering habitat is essential for coho salmon because juvenile coho salmon remain in the Trinity River Basin for their first winter and into the following spring. Preferred overwintering habitats are large mainstem, backwater, and secondary channel pools containing large woody debris, and undercut margins and debris near riffle margins (Hartman, 1965; Bustard and Narver, 1975). Instream residency occurs throughout the upper mainstem from Lewiston downstream to at least the confluence with the North Fork.

Outmigration of 1-year-old coho salmon smolts begins in February and continues through May. Peak outmigrations occur in May in the Trinity River near Willow Creek (USFWS, 1998). Outmigrant monitoring on the mainstem Trinity near Junction City and Willow Creek from 1992 to 1995 indicated that natural coho salmon smolt production is low and typically represents less than 3 percent of the total annual coho salmon smolt catch (Glase, 1994a).

3.1.1.3 Steelhead

The National Marine Fisheries Service (NMFS) recognizes two ecotypes of steelhead based on sexual maturity at the time of river entry (NMFS, 1994). Steelhead that enter the river in an immature state and mature several months later are termed "stream-maturing"; these are the summer-run steelhead. "Ocean-maturing" steelhead enter the river system while sexually mature and spawn shortly thereafter; ocean-maturing steelhead are referred to as "winter-run" steelhead. Portions of both groups may enter freshwater in spring or fall and are then called "spring-" or "fall-run" steelhead (Barnhart, 1986).

In addition to runs of adult steelhead, the Klamath and Trinity Rivers also support a run of immature steelhead known as "half-pounders", which spend only 2 to 4 months in the ocean before returning to the river in late summer and early fall (Barnhart, 1986). Half-pounders feed extensively in freshwater and are highly prized by sport anglers. Half-pounders overwinter in the river without spawning before returning to the ocean, and return as mature adults during subsequent migrations. Half-pounders have a very limited geographic distribution and are known to exist only in the Rogue, Klamath-Trinity, Mad, and Eel river systems.

Steelhead enter the Klamath-Trinity Rivers throughout most of the year. Summer-run adults enter the stream between May 1 and October 30 (Barnhart, 1986) and hold in the river for several months before spawning. Summer-run steelhead commonly reach Lewiston (RM 112.0) by early June and continue to arrive through July. They enter major tributary streams by August (Leidy and Leidy, 1984) and remain in deep pools until they spawn in February (Barnhart, 1986). Winter-run steelhead enter the river between November 1 and April 30 and hold in relatively high-velocity habitats, such as riffles and runs. They spawn in April and May (Barnhart, 1986). Summer- and winter-run steelhead, therefore, are isolated temporally and spatially. They do not interbreed because summer-run adults generally use areas that are farther upstream than areas used by winter-run adults (Barnhart, 1986).

Spawning of all steelhead races in the Trinity River typically begins in February, peaks in March or April, and ends in early June (Leidy and Leidy, 1984). After emergence from spawning gravel, steelhead fry and juvenile steelhead use habitats similar to those of juvenile salmon, although rearing steelhead prefer higher velocities than do salmon of similar size. Everest and Sedell (1983) identified key winter habitat for steelhead as areas with boulder-rubble stream margins that are approximately 12 inches deep with low to near zero water velocities.

Outmigration of steelhead smolts from the Trinity River above Junction City (RM 79.6) begins in early spring of their second or third year and peaks in late April and early May (Glase, 1994a). Outmigration near Willow Creek (RM 24) begins in late March and early April, peaks in early May, and continues throughout June (USFWS, 1998).

3.1.1.4 Summary of Habitat Requirements

Although the three species of anadromous salmonids that inhabit the Trinity River have unique habitat preferences and timing for their spawning, growth, and outmigrating life stages, these species share common life-history requirements that should be considered when making crucial decisions regarding restoration of the fisheries:

1. Spawning pairs require adequate space to construct and defend their redd, which commonly is associated with unique instream habitat features;
2. Spawning gravels with a low percentage of fine sediment facilitate adequate subgravel flow through the interstitial spaces in the redd,

increasing successful egg hatch and sac fry survival. Excessive sand and silt loadings reduce the survival of eggs and sac fry, as well as fry emergence success;

3. Salmonid fry require low-velocity, shallow habitats— and, as they grow, a variety of habitat types are required that include faster, deeper water and instream cover;

4. Because of their extended residency in the Basin, coho salmon and steelhead must have abundant overwintering habitat composed of low-velocity pools and interstitial cobble spaces; and

5. Smolt survival is a function of fish size, water temperatures in the spring and early summer, and streamflow patterns.

3.1.2 Abundance Trends

Pre-TRD data on salmon abundance in the Trinity Basin are sporadic (See Appendix D). The most continuous data set available is that for post-TRD fall-run chinook. Data for steelhead and coho salmon commonly are unavailable or of poor quality: the adults of these species spawn during high flows, making the operation of fish-counting weirs and other standard methodologies at best inaccurate (or impossible) in some years. Another factor confounding the assessment of adult returns is the number of hatchery-produced fish that elect not to re-enter the hatchery but instead spawn in the river. This behavior artificially inflates annual inriver spawning escapements, so that the naturally produced spawning populations appear larger than they are. The following sections describe the data available for pre- and post-TRD populations, and when available, the relative numbers (proportions) of hatchery-produced and naturally produced fish contributing to the inriver spawning escapement. For the purposes of this evaluation, the term "inriver spawners" and "inriver spawning escapement" refers to fish that spawn in the Trinity River and excludes fish that return to the TRFH. "Naturally produced" refers to fish whose parents were inriver spawners; "hatchery-produced" refers to fish whose parents were spawned at TRFH.

3.1.2.1 Chinook Salmon

Information specific to the Trinity River chinook salmon populations prior to the construction of the TRD is sparse (Table 3.4). The Tribes along the banks of the lower Trinity and Klamath Rivers have always depended extensively on abundant populations of salmon and steelhead for their subsistence, commercial,

Table 3.4. Pre-TRD salmonid abundance information available for the Trinity River. No distinction was made between spring- and fall-run chinook for these estimates.

Species	Year(s)	Number of Fish	Location/Reach	Type of Data
Chinook salmon	1912	141,000	Klamath Estuary	Harvest
Chinook salmon	1944, 1945, 1955, 1956, 1963	average = 47,600 (min = 19,000, max = 75,600)	Trinity R., above the North Fork and above Lewiston	Spawning escapements (see Appendix E for more details)
Chinook salmon	1944, 1945, 1955, 1956, 1963	average = 18,834 (min = 10,000, max = 30,134)	Trinity R., above the North Fork to Lewiston	Spawning escapements (see Appendix E for more details)
Coho salmon	historic estimate	5,000	Trinity R., above Lewiston	Spawning escapement (USFWS/CDFG, 1956)
Steelhead	historic estimate	10,000	Trinity R., above Lewiston	Spawning escapement (USFWS/CDFG, 1956)

and ceremonial uses. Thousands of salmon were harvested annually (Hewes, 1942). In the mid-1800's, spring-run chinook salmon were considered the most abundant race in the Klamath Basin. After gold was discovered in the Klamath and Trinity Rivers, canneries began operating along the Klamath estuary in the late 1800's. At the harvest peak in 1912, approximately 141,000 salmon were harvested and canned. In 1915, approximately 72,400 chinook salmon were harvested from the Klamath River and its tributary streams. By the early 1900's, over-harvesting had reduced the spring-run populations to low levels, making the fall-run chinook the dominant run in the Basin (Snyder, 1931).

> "The Tribes along the banks of the lower Trinity and Klamath Rivers have always depended extensively on abundant populations of salmon and steelhead for their subsistence, commercial, and ceremonial uses."

Historical (pre-TRD) estimates of fall-run chinook salmon entering the Trinity River were made by various investigators, and data for some years were reinterpreted using different methods, leaving large discrepancies in estimates for the same year. Hamaker (1997) reviewed historical run-sizes in the literature (Appendix D) and found that pre-TRD spawning escapement estimates for the Trinity River upstream from the North Fork Trinity River confluence that were not affected by the TRD ranged from 19,000 to 75,600 chinook salmon, with an average escapement of 47,600 (Table 3.4). Estimates for spawning escapements from the North Fork Trinity River confluence to Lewiston ranged from 10,000 to 30,134 chinook salmon, averaging 18,834. These North Fork to Lewiston estimates exclude the 1963 escapement because spawner distribution was affected by the TRD that year.

For the period 1982 to 1995, total inriver spawning escapement (jacks and adults) in the Trinity River Basin above Willow Creek ranged from 5,249 to 113,007 and averaged 35,230 (Appendix E, Table E.1). Spawning escapement of adult (jacks excluded) fall-run chinook salmon ranged from 4,867 to 92,548 fish and averaged 25,359 during this period. Substantial numbers of these inriver spawners were hatchery-produced. Based on ad-clip rates observed at the TRFH and the Willow Creek weir from 1982 to 1995, the proportion of inriver spawners (jacks and adults; adult-only information is unavailable) that are naturally produced ranged from 10 to 94 percent, and averaged 44 percent. After removing the numbers of hatchery-produced fall-run chinook salmon, the inriver spawning escapement (jacks and adults) of naturally produced fall-run chinook salmon ranged from 2,348 to 41,663 and averaged 11,044.

Comparisons between pre- and post-TRD averages are problematic (Figure 3.2) because: (1) few complete pre-TRD estimates exist; (2) only fish spawning in the river above the North Fork were estimated prior to TRD; and (3) those estimates do not distinguish between spring- and fall-run chinook, although Snyder (1931) indicates that the fall-run chinook was the dominant run in the Klamath River estuary by the 1930's. The post-TRD average (35,230) for spawning fish is 12,300 less than the average pre-TRD spawning escapement (47,600). If the numbers of straying hatchery fish that spawn in the river are removed, the post-TRD average for naturally produced fish (11,044) is less than a quarter of the average pre-dam estimate and only slightly more than half the minimum pre-TRD spawning escapement (19,000). Hatchery-origin fish commonly constitute a large part of the fish spawning inriver, but increases of naturally produced fish do not follow in subsequent

> The post-TRD proportion of inriver fall-run chinook spawners that are naturally produced ranged from 10 to 94 percent, and averaged 44 percent.

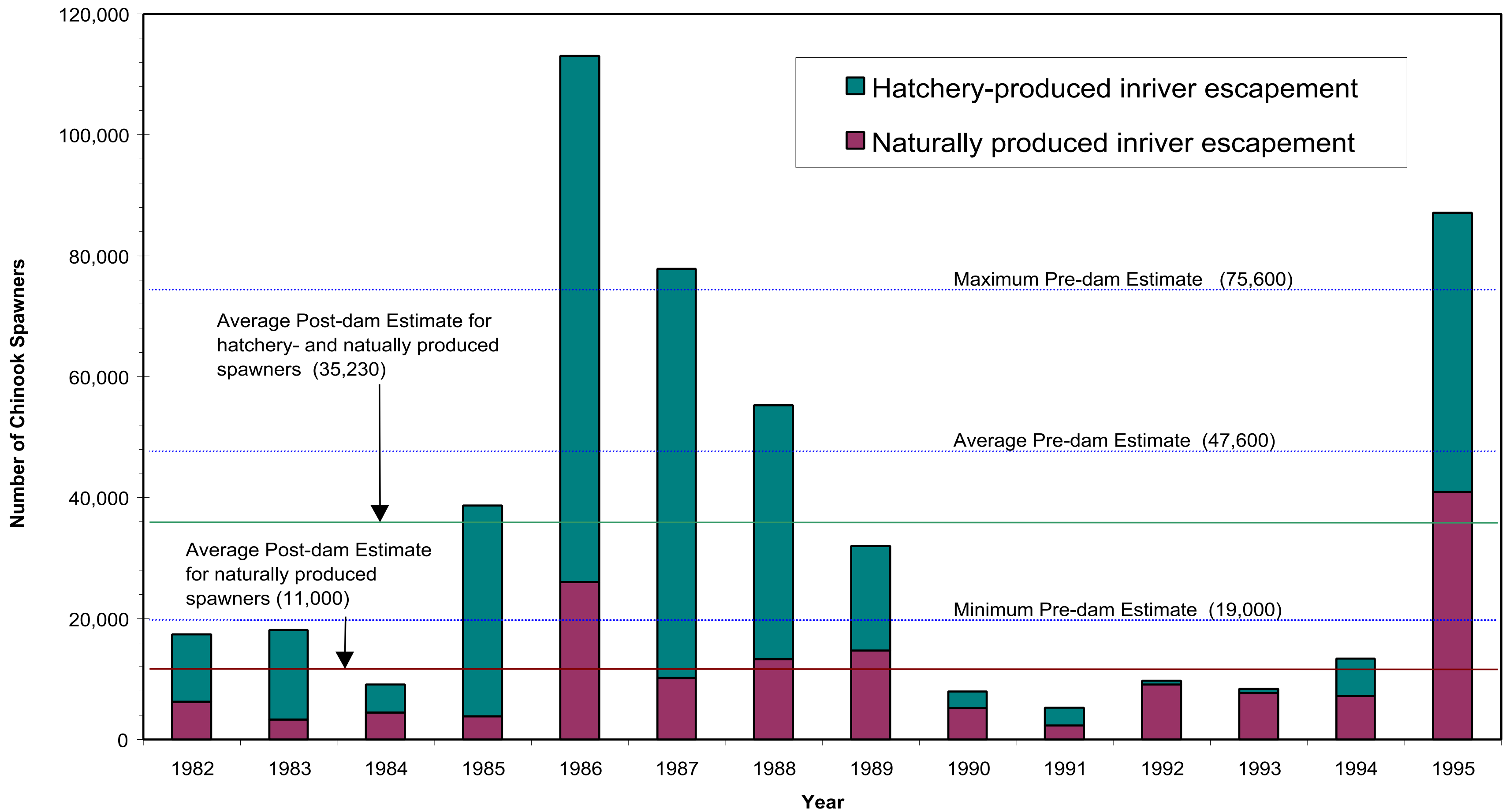


Figure 3.2. Post-TRD fall-run chinook inriver spawner escapements (1982-1995) and the proportion of inriver spawners that were naturally and hatchery-produced in the Trinity River above Willow Creek, compared to historical estimates (1944, 1945, 1955, 1956, and 1963).

years. Offspring of hatchery-produced fish are indistinguishable from offspring of naturally produced fish because neither are marked; therefore, the offspring of any fish spawning in the river is naturally produced. From 1986 to 1989, large numbers of fish spawned inriver, but very few naturally produced fish returned in 1988 to 1994, indicating that in that time frame relatively few progeny of these inriver spawning escapements survived to return as adults.

From 1978 to 1994, numbers of spring-run chinook salmon spawners (jacks and adults) above Junction City ranged from 1,360 to 39,570 and averaged 9,800 (Table 3.5). From 1982 to 1994, the naturally produced component of the inriver spawners ranged from 0 to 100 percent and averaged 32 percent. During this period, numbers of naturally produced spring-run chinook salmon ranged from 0 to 6,214 and averaged 1,551 fish. Spring-run chinook salmon that spawned in the North Fork Trinity River, New River, and South Fork Trinity River were not included in these estimates because these tributaries are below the Junction City Weir.

> "…the naturally produced component of the inriver spring-run chinook spawners ranged from 0 to 100 percent and averaged 32 percent."

3.1.2.2 Coho Salmon

Information on coho salmon in the Trinity River prior to TRD construction is sparse. Moffett and Smith (1950) reported that coho salmon were usually observed in the Hoopa Valley by October, but that they were not common in the Trinity River above Lewiston. Other information suggests that coho salmon adults and juveniles did use habitat in the Trinity River above Lewiston: Approximately 5,000 adult coho salmon migrated past Lewiston prior to TRD construction according to USFWS/CDFG (1956) (Table 3.4). Additionally, fingerling coho salmon were rescued from an irrigation diversion in 1949, 1950, and 1951 near Ramshorn Creek, which enters the Trinity River approximately 42 miles upstream from Lewiston (USFWS/CDFG, 1956).

Between the time that the TRD was completed (1964) and 1977, two coho salmon escapements were estimated for the Trinity River upstream from the North Fork. In 1969 and 1970, the CDFG estimated the coho salmon run at 3,222 and 5,245 fish, respectively (Smith, 1975; Rogers, 1973 as cited by Hubbell 1973). Since 1978, the inriver spawners of coho salmon (jacks and adults) in the Trinity River above Willow Creek have ranged from 558 to 32,373, and averaged 10,192 fish (Table 3.5; Appendix E, Table E.4). From 1991 to 1995, the naturally produced contribution to the inriver escapement ranged from 0 to 14 percent, and averaged 3 percent. Adjustments to the inriver spawner escapement that exclude hatchery-produced coho salmon indicated that an average of 202 naturally produced coho salmon returned annually (Appendix E, Table E.4); i.e., the Trinity River inriver coho salmon population is predominantly of hatchery origin.

> The Trinity River coho salmon inriver spawning escapement is predominantly of hatchery origin.

3.1.2.3 Steelhead

Estimating run sizes of Trinity River steelhead has always been difficult because many steelhead enter the river after fall rains increase flow beyond the operational limits of fish-counting weirs; steelhead that migrated from late fall to late spring were therefore often missed in fish-counting operations. Prior to TRD construction, USFWS/CDFG (1956) estimated that 10,000 steelhead migrated past Lewiston (Table 3.4), but no estimates were made for the river below Lewiston. At one time, spawning was extensive in many tributaries, and considerable mainstem spawning occurred in some years prior to TRD construction (Moffett and Smith, 1950). However, mainstem spawning adults were considered to be a minority of the overall population (USFWS/CDFG, 1956).

Table 3.5. Post-TRD average spawning escapements (jacks and adults) for the Trinity River. Note: all averages are calculated on annual values and can not be directly derived from the information presented in this table.

Species	Average Inriver Escapement (hatchery - and naturally produced spawners)	Average Inriver Escapement (naturally produced spawners)	Average Hatchery Percentage of the Inriver Spawners	River Reach
Fall-Run Chinook	35,231	11,044	56	Willow Creek to Lewiston Dam
Spring-Run Chinook	9,800	1,550	68	Junction City to Lewiston Dam
Coho	10,190	200	97	Willow Creek to Lewiston Dam
Fall-Run Steelhead	9,160	4,724	30	Willow Creek to Lewiston Dam

Steelhead spawning surveys in the Trinity River and several tributaries between North Fork Trinity River and Lewiston in 1964 provided an estimate of 7,449 to 8,684 fish (LaFaunce, 1965). LaFaunce (1965) stated that these surveys provided minimal estimates of steelhead abundance because of the short duration of the surveys (March 30 to May 12) and the inability to separate multiple redds. A 1972 steelhead spawning survey indicated that steelhead use of several tributaries below Lewiston had declined since 1964 (Rogers, 1973). The number of steelhead using tributaries below Lewiston in 1964 was likely to have been greater than the number prior to TRD construction because fish that reared in areas upstream from Lewiston were now precluded from their natal habitats and forced to spawn in the downstream tributaries. Potentially, over time, steelhead numbers may have declined toward levels that could normally be sustained by these tributaries below the dams.

CDFG produced 12 estimates of steelhead escapement upstream from Willow Creek from 1980 to 1995, and estimated the hatchery contribution to the in-river spawner escapement in six of these years (Appendix E, Table E.5). In-river spawner escapement in the Trinity River Basin above Willow Creek ranged from 1,977 to 28,933 and averaged 9,160 (Table 3.5). The contribution of naturally produced steelhead to the in-river spawner escapement ranged from 57 to 88 percent and averaged 70 percent for the six years for which data were available (Appendix E). Adjustments to the annual in-river escapement to exclude hatchery-produced steelhead indicated that escapement of naturally produced steelhead ranged from 1,176 to 14,462 and averaged 4,724 (Table 3.5). However, the data collected to generate these estimates only account for the fall-run and the early portion of the winter-run and therefore assess only a portion of the Trinity River steelhead population.

> "The contribution of naturally produced steelhead to the in-river spawner escapement ranged from 57 to 88 percent and averaged 70 percent . . . "

The healthiest populations of summer-run steelhead in the Trinity River Basin are in the North Fork Trinity River and New River (Appendix E, Table E.6). Canyon Creek and the South Fork Trinity River also support small populations of summer-run steelhead.

3.1.2.4 Summary of Abundance Trends

Current populations of naturally produced Trinity River anadromous salmonids are at low levels. The large spawning escapements since 1978 were typically dominated by hatchery-produced fish that spawned in the natural areas of the Trinity River and are not indicative of healthy spawning and rearing conditions in the Trinity River. Typically, more fish spawn in the river than are spawned at the hatchery (see Appendix E), but fewer fish that were spawned in the river as eggs survive to return as adults. This poor survival probably indicates poor habitat conditions for early life stages (eggs, fry, and juvenile), assuming that hatchery-produced and naturally produced fish are subjected to the same environmental conditions from smolt to adult. The relatively large contribution of hatchery-produced fish can be attributed to their increased survival during incubation and early life stages (egg, fry, and juvenile) under controlled hatchery conditions.

An indicator of the poor condition of the freshwater habitat of the Trinity River is the status of coho salmon, whose extended freshwater life history makes them more dependent than chinook salmon on freshwater habitat for rearing. On May 6, 1997, the National Marine Fisheries Service (NMFS) issued a final rule listing the coho salmon that return to Klamath and Trinity Rivers, the Southern Oregon/Northern California Coast Evolutionary Significant Unit (ESU), as threatened, pursuant to the Endangered Species Act (ESA) (62 Fed. Reg. 24588). The final rule estimated that California populations of coho salmon — fewer than 10,000

"Current populations of naturally produced Trinity River anadromous salmonids are at low levels. The large spawning escapements since 1978 were typically dominated by hatchery-produced fish that spawned in the natural areas of the Trinity River and are not indicative of healthy spawning and rearing conditions in the Trinity River."

naturally producing adults — could be less than 6 percent of their abundance in the 1940's. The final rule also noted that large hatchery programs are an issue. The final rule recognized that various habitat declines affected coho salmon populations, including channel morphology changes, substrate changes, loss of off-channel rearing habitats, declines in water quality (e.g., elevated water temperatures), and altered streamflows. On November 25, 1997, NMFS proposed that critical habitat be designated for coho salmon in the Trinity River (62 Fed. Reg. 62741).

Steelhead populations in the Klamath and Trinity Rivers were also proposed as threatened pursuant to the ESA (62 Fed. Reg. 43937), and controversy delayed the final decision until February 1998 (62 Fed. Reg. 43974). NMFS determined that Klamath Mountains Province ESU steelhead did not warrant listing at the time, but do warrant classification as a candidate species (63 Fed. Reg. 13347). NMFS will reevaluate the status of steelhead within 4 years to determine if listing is warranted. The chinook salmon of this ESU are also candidate species pursuant to the ESA.

3.1.3 Fish Disease Monitoring

The Service's California-Nevada Fish Health Center has conducted disease surveys on both naturally produced and hatchery-origin salmonids produced in the Trinity River since 1991 (Foott, 1996; pers. comm.). Samples were collected from juvenile salmonids at the TRFH prior to release. A second set of samples was collected from both hatchery and naturally produced salmonids captured in an outmigrant trap located 90 miles downstream, near Willow Creek.

Several pathogens were detected, including infectious hematopoietic necrosis virus (IHNV), Erythrocytic Inclusion Body Syndrome (EIBS) viral inclusions, *Renibacterium salmoninarum*, *Nanophyetus salmonicola metacercaria*, and *glochidia* (larval mollusks). High infestations of the *N. salmonicola metacercaria* have consistently been observed in both hatchery and natural salmonids captured in the outmigrant trap and there is considerable concern that these infestations may negatively affect survivability of salmon smolts (Foott and Walker, 1992).

The parasitic trematode, *N. salmonicola*, infects multiple hosts during its life cycle. The initial host for the parasite is a freshwater snail, probably *Oxytrema* or *Juga* species. Once in the snail, the larvae develop into cercariae. The cercariae burrow out of the snail when ready and begin their search for their secondary host, a fish. When contact is made with a fish, the cercariae burrow into the fish and enter the bloodstream. Once in the bloodstream, the parasites will usually travel to the kidney, heart, or gills where they develop into cysts.

Currently, Trinity River coho salmon are listed as threatened pursuant to the Endangered Species Act, and chinook salmon and steelhead are candidate species. The final rule that listed coho salmon recognized that various habitat declines affected coho salmon populations, including channel morphology changes, substrate changes, loss of off-channel rearing habitats, declines in water quality (e.g., elevated water temperatures), and altered streamflows.

Nanophyetus infection rates in Trinity River juvenile chinook salmon collected in the spring and fall were as high as 2,500 and 5,000 cysts per gram of kidney, respectively (Foott and Walker, 1992). Hatchery salmon, which were free of *Nanophyetus* infections at the hatchery, had *Nanophyetus* infections that were nearly equal to naturally produced chinook salmon after exposure to the trematode in the river for only 2 weeks. Although not proven conclusively, there is a good possibility that an inverse relationship exists between the severity of *Nanophyetus* infections and salt-water survival (Free et al., 1997).

> There is considerable concern that high infestations of the *N. salmonicola* metacercaria may negatively affect survivability of salmon smolts.

The low-flow releases prevalent below the TRD during the spring migration period have improved conditions favoring *N. salmonicola* survival (Foott, 1996, pers. comm.). Low flows increase the time for outmigrating salmon to exit the river system, thus increasing their exposure to *Nanophyetus cercariae.* Lower flows and reduced water velocities also enhance conditions necessary for free-swimming cercaria to locate and infect fish (Foott, 1996, pers. comm.). It seems likely that the elimination of high spring flows, through the operation of the TRD, has improved conditions for the survival and reproduction of snail populations, which could lead to increased numbers of *N. salmonicola* than occurred historically.

3.1.4 Other Fish Species in the Trinity River

Although the primary focus of the TRFE is on anadromous salmonids, the fish community in the Trinity River is composed of several additional species (Table 3.6). Several native species are of biological, cultural, and economic significance, and their life histories and habitat requirements are briefly outlined here to illustrate the diversity of habitat required by the fish community.

Pacific Lamprey (*Entosphenus tridentatus*) are harvested by the Hupa, Karuk, and Yurok Indians and remain an integral part of their culture today. Pacific lamprey are a parasitic species of anadromous lamprey native to the Trinity River. Adult Pacific lamprey migrate upstream and spawn during the spring (Moyle, 1976). Eggs are deposited in pits excavated in gravel and cobble substrates, which are usually associated with run and riffle habitats similar in character to salmon spawning areas. The eggs hatch into a non-parasitic larval stage, referred to as an "ammocoete". Ammocoetes drift downstream into slow-water habitats, where they burrow into sand or silt substrates. They spend from 4 to 5 years in freshwater, where they feed on organic detritus. The juveniles metamorphose into the adult form just prior to seaward migration, at which time they become parasitic. Adults remain in the ocean usually 6 to 18 months before they begin their spawning migration.

Green Sturgeon (*Acipenser medirostris*) are harvested by the Tribal fisheries in the lower Klamath and Trinity Rivers and these fish have cultural significance to the Hupa, Karuk, and Yurok Indians. From 1982 through 1992, the harvest of green sturgeon on the Yurok Indian Reservation was fairly consistent, averaging just under 300 fish (Craig and Fletcher, 1994). Green sturgeon migrate up the Klamath and Trinity Rivers between late February and July to spawn. Gray's Falls (RM 43) is believed to be the upstream limit of sturgeon migration in the Trinity River. Sturgeon spawn from March through July, peaking mid-April to mid-June (Emmett et al., 1991). Juvenile green sturgeon are found in the Trinity River near Willow Creek from June through September (USFWS, 1998), and appear to outmigrate during their first summer to the lower river or estuary, where they rear for some time before moving to the ocean.

Table 3.6. Fish species found in the Trinity River.

Common name	Scientific Name
Pacific lamprey*	*Entosphenus tridentatus*
Green sturgeon*	*Acipenser medirostris*
American shad	*Alosa sapidissima*
Brown trout	*Salmo trutta*
Steelhead/rainbow trout*	*Oncorhynchus mykiss*
Coho salmon*	*Oncorhynchus kisutch*
Chinook salmon*	*Oncorhynchus tshawytscha*
Chum salmon	*Oncorhynchus keta*
Kokanee salmon	*Oncorhynchus nerka*
Golden shiner	*Notemigonus crysoleucas*
Speckled dace*	*Rhinichthys osculus*
Minnows	*Pimephalus spp.*
Klamath smallscale sucker*	*Catostomus rimiculus*
Threepine stickleback	*Gasterosteus aculeatus*
Black crappie	*Pomoxis nigromaculatus*
Sunfish spp.	*Lepomis spp.*
Largemouth bass	*Micropterus salmoides*
Sculpin*	*Cottus spp.*

* indicates species native to the Trinity River.

Speckled Dace (*Rhinichthys osculus*) are a native species common throughout the Trinity River and its tributaries. Speckled dace are most abundant in cobble-strewn riffles, where they hide during the day and feed at night (Moyle, 1976). Speckled dace are small fish (< 6 inches), and few live beyond their third winter. Adults spawn during the spring, and fry are common during late spring and summer months in shallow edgewaters with moderate current.

Klamath Smallscale Suckers (*Catostomus rimiculus*) are most abundant in slow-run and pool habitats (Moyle, 1976). Suckers spawn during the spring in run habitats and tributary streams. Fry and juvenile suckers have been observed in the mainstem in slow edgewater habitats in both the mainstem and side channels by Service biologists during late spring and summer months.

3.2 Wildlife Resources

Although the primary focus of the TRFE is on anadromous salmonids, the Trinity River is important to many species of wildlife. Riparian habitats in unregulated rivers in northwestern California support diverse vertebrate and invertebrate communities. These species are adapted to and depend on annual flood events to create river and floodplain habitats, such as seasonally flooded marshes and side channels, early successional willow vegetation, and shallow, low water-velocity areas along the main channel (i.e., backwater and edgewater pools) (Wilson et al., 1991; Lind et al., 1995; Reese, 1996; Reese and Welsh, 1998). Many wildlife species also have adapted their breeding, migration, and foraging cycles (Table 3.7) to the natural flow cycles of the river (Lind et al., 1996). Growth, development, behavior, and survival of ectothermic animals (amphibians, reptiles, invertebrates) are highly dependent on temperature. Thus, the timing and temperature of water releases could have significant effects on many species.

Little pre-TRD information exists on riparian-associated wildlife species in the Trinity River Basin. Many sensitive wildlife species occur in riparian habitats along the mainstem Trinity River today and likely occurred prior to the construction of the Trinity and Lewiston Dams: foothill yellow-legged frog (California species of special concern [CSSC]); western pond turtle (CSSC); bald eagle (Federal ESA-listed threatened); osprey (CSSC); yellow warbler (CSSC); willow flycatcher (State threatened); yellow-breasted chat (CSSC); and black-capped chickadee (CSSC) (Wilson et al., 1991; Lind et al., 1995; BLM, 1995). There are also three bat species (pallid, little brown myotis, and Townsend's western big-eared [CSSC]) that are typically associated with riparian habitats, but their historical and current status in the Trinity River Basin is unknown (BLM, 1995).

Two sensitive and highly aquatic species have been studied in the Trinity River Basin: the foothill yellow-legged frog (*Rana boylii*) and the western pond turtle (*Clemmys marmorata*) (Lind et al., 1995; Reese, 1996; Reese

Table 3.7. Annual cycles of amphibians and reptiles along the mainstem Trinity River (compiled by A. Lind, USDA Forest Service - 11/95). See footnotes on next page.

	Landscape use													
Month	PGS [i] larvae	PGS adults	RSN larvae	RSN adults	WTO egg/tad	WTO toads	PTF egg/tad	PTF frogs	FYF egg/tad	FYF frogs	BLF all life stgs	WPT females	WPT males	Garter Snakes
Jan-Feb[ii]	tribs/ river, in substrate	on land, active ?	sloughs & river	on land, active ?	-------[iii]	on land, inactive ?	-------	on land, active ?	--------	on land, inactive ?	sloughs, marshes	on land, hiber-nating	on land, hiber-nating	on land, hiber-nating
March	tribs/ river, in substrate	tribs, breeding	sloughs & river	sloughs, breeding	-------	river	sloughs & vern pools	river & other riparian	-------	sloughs & river	sloughs, marshes	moving to river	moving to river	on land, active ?
April	tribs/ river, in substrate	tribs, breeding	sloughs & river	sloughs, breeding	river, slow margins (eggs)	river, slow margins	sloughs & vern pools	river & other riparian	river, bar margins (eggs)	river, bar margins	sloughs, marshes	in or near river	in or near river	riparian & river shore
May	tribs & river	tribs, breeding	sloughs & river	sloughs, breeding	river, slow margins (eggs)	river, slow margins	sloughs & vern pools	river & other riparian	river, bar margins (eggs)	river, bar margins	sloughs, marshes	nesting, land (25%)	main river channel	riparian & river shore
June	tribs & river	on land, inactive	sloughs & river	sloughs, breeding	river, slow margins (eggs)	river, slow margins	sloughs & vern pools	river & other riparian	river, bar margins (eggs)	river, bar margins	sloughs (eggs)	nesting, land (50%)	main river channel	riparian & river shore
July	tribs & river	on land, inactive	sloughs & river	on land, inactive	river, slow margins	river shore & margins	sloughs & vern pools	river & other riparian	river, bar margins	river shore & margins	sloughs (eggs)	nesting, land (25%)	main river channel	riparian & river shore
August	tribs & river	on land, inactive	sloughs & river	on land, active ?	river, slow margins	river shore & margins	-------	river & other riparian	river, bar margins	river shore & margins	sloughs, marshes	main river channel	main river channel	riparian & river shore
Sept	tribs & river	on land, inactive	sloughs & river	on land, active ?	river, slow margins	river shore & margins	-------	river & other riparian	river, bar margins	river shore & margins	sloughs, marshes	moving onto land	moving onto land	riparian & river shore
Oct	tribs & river	on land, inactive	sloughs & river	on land, active ?	-------	river shore & margins	-------	river & other riparian	river, bar margins	sloughs & river	sloughs, marshes	on land, hiber-nating	on land, hiber-nating	riparian & river shore
Nov-Dec[2]	tribs/ river, in substrate	on land, active ?	sloughs & river	on land, active ?	-------	on land, inactive ?	-------	on land, active ?	-------	on land, inactive ?	sloughs, marshes	on land, hiber-nating	on land, hiber-nating	on land, hiber-nating

Table 3.7 cont.. Annual cycles of amphibians and reptiles along the mainstem Trinity River (compiled by A. Lind, USDA Forest Service - 11/95).

Footnotes: (for Table 3.7)

i. Info on annual cycles was derived as follows for each species (eg., PGS) and life stage (eg., adult)
PGS - Pacific giant salamander (*Dicamptodon tenebrosus*) - literature (see below)
RSN - rough-skinned newt (*Taricha granulosa*) - literature and pitfall trapping (Welsh, unpublished data)
WTO - western toad (*Bufo boreas*) - literature and field notes (Lind, unpublished data)
PTF - Pacific treefrog (*Hyla regilla*) - literature and field notes (Lind, unpublished data)
BLF - bullfrog (*Rana catesbeiana*) - literature and field notes (Lind, unpublished data)
FYF - foothill yellow-legged frog (*Rana boylii*) - literature and field surveys (Lind, unpublished data)
WPT - western pond turtle (*Clemmys marmorata*) - radio telemetry study (Reese, unpublished data)

ii. Detailed information is not provided for November through February because most species are on land and inactive in the Trinity Basin during these months.

iii. ----- indicates that this life stage does not exist at this time of year.

References

Dethlefsen, E.S. 1948. A subterranean nest of the Pacific giant salamander, *Dicamptodon ensatus*. The Wasmann Collector. 7:81-84.

Leonard, W.P., H.A. Brown, L.L.C. Jones, K.R. McAllister, and R.M. Storm. Amphibians of Washington and Oregon. Seattle Audubon Society, Seattle, Washington. 168pp.

Lind, A.J. 1990-1995. Unpublished data. USDA Forest Service, Pacific Southwest Research Station, Arcata, California.

Nussbaum, R.A., E. D. Brodie, and R.M. Storm. 1983. Amphibians and Reptiles of the Pacific Northwest. University of Idaho Press, Moscow. 332pp.

Nussbaum, R.A. and G.W. Clothier. 1973. Population structure, growth, and size of larval *Dicamptodon ensatus*. Northwest Science 47:218-227.

Packer, W.C. 1960. Bioclimatic influences on the breeding migration of *Taricha rivularis*. Ecology. 41:510-517.

Propper, C.R. 1991. Courtship in the rough-skinned newt *Taricha granulosa*. Animal Behavior 41:547-554.

Reese, D.A. 1992-1995. Unpublished data. USDA Forest Service, Pacific Southwest Research Station, Arcata, California.

Stebbins, R.C. 1985. Western Amphibians and Reptiles. Houghton Mifflin Company, Boston. 336pp.

Twitty, V., D.Grant, and O. Anderson. 1964. Long distance homing in the newt *Taricha rivularis*. Proceedings of the National Academy of Sciences 51:51-58.

Welsh, H.H. Jr. 1990. Unpublished data. USDA Forest Service, Pacific Southwest Research Station, Arcata, California.

> "Riparian habitats in unregulated rivers in northwestern California support diverse vertebrate and invertebrate communities. These species are adapted to and depend on annual flood events to create river and floodplain habitats."

and Welsh, 1998; Reese and Welsh, in press). Foothill yellow-legged frogs are active during spring, summer, and fall along the river margins and in flowing side channels, and probably hibernate in the winter. Eggs are deposited between April and June in shallow, low-velocity areas along rocky, sparsely vegetated river bars (Lind et al., 1996). Upon metamorphosis, most juveniles migrate upstream, probably as a compensating mechanism for downstream drift of larvae (CDFG, 1994b). Surveys of foothill yellow-legged frogs on the Trinity River found that their distribution is related to the distribution of early successional riparian and gravel-bar habitats (Lind et al., 1996). Greater numbers of frogs were found in reaches farther downstream from the dam, where the gravel bar habitats are in greater abundance. The loss of open, rocky, shallow river bars in the upper river has probably contributed to a decline in foothill yellow-legged frog populations (Lind et al., 1996), and the absence of these habitats may deter young frogs from migrating upstream where habitat is less suitable.

Yellow-legged frog egg and larvae survival depends on timing and volume of runoff events (Lind et al., 1996). From the onset of oviposition, yellow-legged frogs require a minimum of 15 weeks to metamorphose (CDFG, 1994b), and are extremely vulnerable to fluctuating flows during this period. Unhatched eggs subjected to a high-flow event are generally washed away (Lind et al., 1996). Larve that hatch prior to a high-flow event are more likely to survive depending on the rate of fluctuation. Rapidly ascending or descending water levels can decrease survival because larvae have difficulty tracking rapidly changing water levels and cannot find appropriate habitat before they are washed away or stranded (Lind et al., 1996).

It is suspected that yellow-legged frogs use environmental cues such as temperature and rainfall patterns to initiate or suspend breeding activities (Lind et al., 1996). Thus, in an unregulated river the frogs are effectively able to avoid depositing eggs during periods of highly fluctuating flows, which are so detrimental to eggs and larvae. On the Trinity River, however, yellow-legged frogs are often subjected to releases that are not in sync with their environmental cues, resulting in high egg and larvae mortality (Lind et al., 1996).

In summer, water temperatures of TRD releases are generally lower than what yellow-legged frogs have adapted to on the Trinity River. Low temperatures retard egg and larvae development, and prolong the period in which they are vulnerable to fluctuating flows and to predators.

Since the construction of TRD, yellow-legged frogs in the upper river have been subjected to decreasing habitat availability, unpredictable timing and volume of releases, and lower summer water temperatures. Thus, frogs have probably had to deposit eggs in faster, deeper water more vulnerable to scouring flows; oviposition has often occurred during periods when eggs and

> "Greater numbers of frogs were found in reaches farther downstream from the dam, where the gravel bar habitats are in greater abundance. The loss of open, rocky, shallow river bars in the upper river has probably contributed to a decline in foothill yellow-legged frog populations."

larvae are likely to be washed away or stranded; and the eggs and larvae have taken longer to develop in the cooler water extending the vulnerable period. Also, upstream migration may have been reduced due to sparse upstream habitat.

Since the construction of TRD, the loss of alternate point bars has resulted in fewer deep pool microhabitats used for refuge and also has reduced shallow edgewater used for rearing by western pond turtles.

Western pond turtles are found in and along pool and glide habitats of the main channel, and smaller hatchlings and juveniles are found in backwater pools, shallow river margins, and side channels with vegetation. The lower end of side channels (the alcove) is often scoured during large floods, providing deep slow-velocity pool habitat adjacent to the main channel. These pools are important foraging and thermoregulation sites for western pond turtles (Reese, 1996). Backwater eddies (a common attribute of alcoves) trap logs and other debris, which are used for aerial basking by western pond turtles when air temperatures are greater than water temperatures (CDFG, 1994b). The limited mixing of backwater areas with the mainstem allows surface temperatures to get considerably higher in backwater areas than the mainstem during the summer. This warm surface layer is utilized by western pond turtles for "water basking" when air temperatures become too warm for aerial basking. Mats of submergent vegetation commonly associated with backwater areas are particularly attractive to western pond turtles because they maintain even warmer surface-water temperatures, help turtles maintain their position, and provide immediately accessible cover (CDFG, 1994b). Standing water associated with more isolated backwater areas also provide an abundance of nekton (zooplankton fauna), a major food source for juvenile pond turtles (CDFG, 1994b).

Cooler summer water temperatures probably also affect western pond turtles by slowing growth, and by altering behavior and habitat selection (Lind, pers. comm.). Cooler water temperatures may shorten the turtles' active period, increase aerial basking activity, or force turtles to seek warmer waters in shallower or more isolated backwaters. Warmer winter water temperatures would also affect pond turtles, which may overwinter on land or in water, or remain active in water during the winter depending on temperatures (CDFG, 1994b).

Since the construction of TRD, the loss of alternate point bars has resulted in fewer deep pool microhabitats used for refuge and also has reduced shallow edgewater used for rearing. Densities of western pond turtles in the mainstem Trinity River (2.6 turtles/acre) are very low in comparison to densities on the unregulated South Fork Trinity River (5 turtles/acre) and unregulated Hayfork Creek (up to 300 turtles/acre), a tributary to the South Fork Trinity River (Reese, 1996; Reese and Welsh, in press). In addition, the age structure for these two locations differs from that of the mainstem, which has a more adult-biased population than either of the other two (Reese, 1996; Reese and Welsh, in press). These differences indicate population declines on the mainstem owing to changes resulting from the dams.

In summary, downstream from Lewiston Dam, there have been many changes in riverine and riparian habitats owing to TRD operations. Habitat features such as seasonally flooded marshes and side channels, shallow river margins, cold-water holding pools, and bank undercuts have been reduced or eliminated.

"Habitat features such as seasonally flooded marshes and side channels, shallow river margins, cold-water holding pools, and bank undercuts have been reduced or eliminated. Species that depend on flood-maintained habitats (e.g., foothill yellow-legged frogs, western pond turtles) have been negatively impacted by reductions in flows."

Species that depend on flood-maintained habitats (e.g., foothill yellow-legged frogs, western pond turtles) have been negatively impacted by reductions in flows. The post-project reductions in summer water temperatures (Section 4.3.6) may also affect development rates and other physiological functions of ectothermic wildlife such as amphibians and reptiles (BLM, 1995).

CHAPTER 4 A Historical Perspective to Guide Future Restoration

Describing the present Trinity River system, including its salmonid populations, is relatively easy. Describing its historical condition is more difficult, but possible. Few scientists made detailed measurements of Trinity River ecosystem processes before TRD construction began (pre-TRD). Historical data consist of several sets of aerial photographs, data collected at USGS gaging stations, personal accounts, and a few administrative reports. Aerial photos show that the mainstem below Lewiston had morphological features typical of alluvial rivers; therefore, the geomorphologists' knowledge of contemporary alluvial rivers can be applied to the former mainstem channel. Basic life-history requirements of woody riparian species are known. Similarly, habitat preferences and physiological limitations for salmon and other aquatic species can be determined from present-day studies. By applying present-day knowledge to the past, we can chart the future. A fishery-restoration strategy pursued in this way sidesteps simply treating symptoms: it attempts to remedy causes for the decline of the fishery resources of the Trinity River. A map of the Trinity River from Lewiston Dam to the North Fork Trinity River confluence is shown in Figure 4.1 and the sites discussed are listed in Table 4.1.

4.1 The Trinity River Ecosystem Before the Trinity River Division

When the TRD was constructed in the early 1960's, the Trinity River mainstem was anything but pristine. Undisturbed conditions did not exist anywhere owing to extensive human disturbance to the active channel, floodplain, and hillslopes. The pre-European mainstem from the uppermost section of present-day Trinity Lake to the North Fork Trinity River confluence had extensive floodplains in any reach unconfined by valley walls. Beginning in the mid-1800's gold miners first placer-mined the Basin, sluicing entire hillsides into the

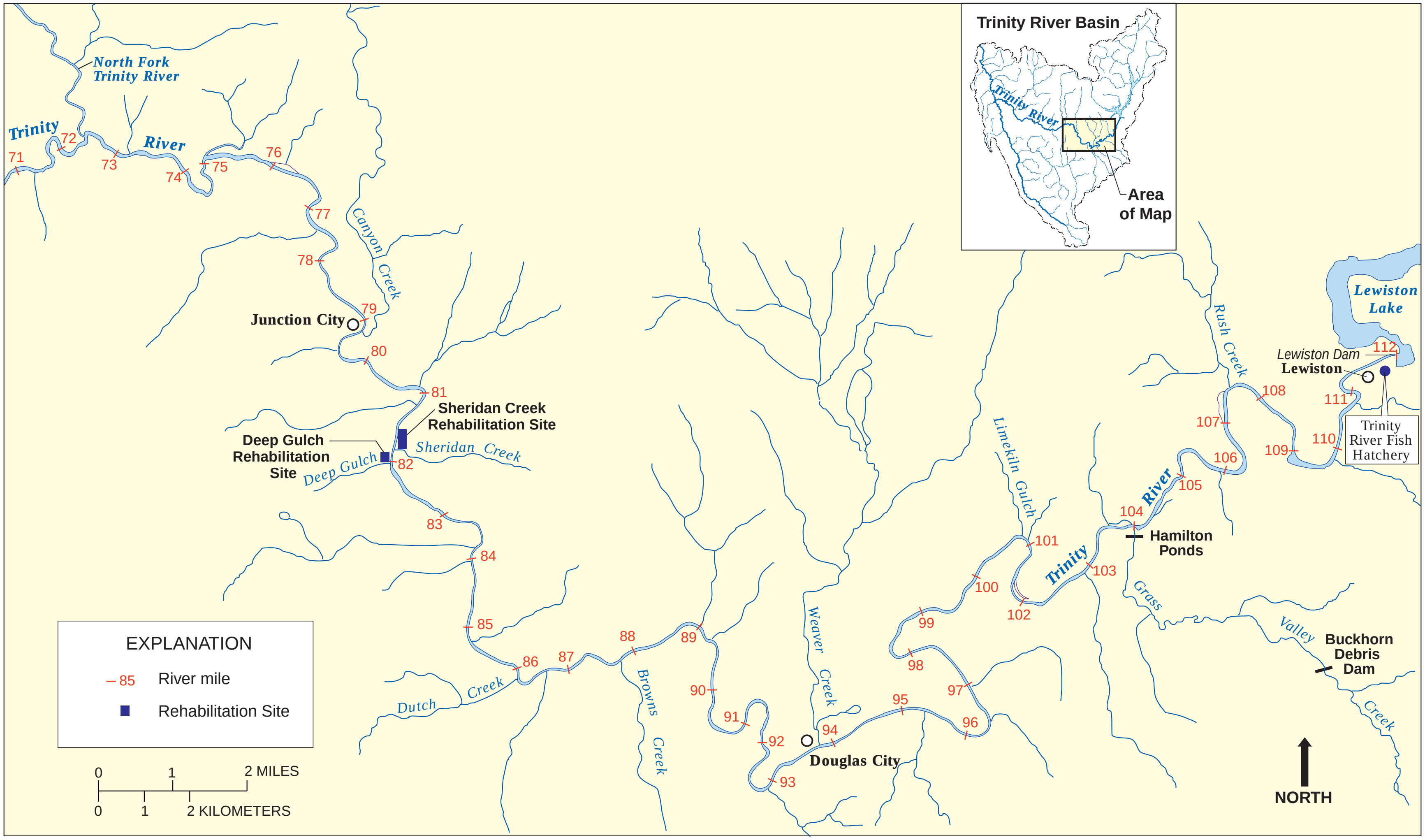


Figure 4.1. The Trinity River mainstem and tributaries from Lewiston to the confluence of the North Fork Trinity River. River mile is the number of river miles upstream from the Trinity River's confluence with the Klamath River.

Table 4.1. Detailed list of Trinity River landmarks downstream from Trinity Dam.

Name	Description	River Mile
Trinity Dam	Storage dam	120.0
Lewiston Dam	Re-regulation and diversion dam	111.9
Dam Site	Sediment budget monitoring site	111.5
Trinity River @ Lewiston	USGS continuous streamflow gaging station (1911-present)	110.9
New Lewiston Bridge	Bridge crossing the Trinity River	110.8
Deadwood Creek	Tributary	110.8
Deadwood Creek @ Lewiston	Sediment budget monitoring site, HVT continuous streamflow gaging station (1997-present)	110.8
Lewiston Cableway	USGS cableway, mainstem sediment transport monitoring site	110.2
Old Lewiston Bridge	Bridge crossing the Trinity River	109.95
Sawmill	Channel morphology monitoring site	108.6
Rush Creek	Tributary	107.5
Rush Creek near Lewiston	Sediment budget monitoring site, HVT continuous streamflow gaging station (1996-present)	107.5
Gold Bar	Channel morphology monitoring site	106.3
Dark Gulch	Tributary	105.9
Bucktail Bank Rehabilitation	Bank rehabilitation project	105.6
Gravel Plant	Channel morphology monitoring site	105.5
Browns Mountain Bridge	Bridge crossing the Trinity River	105.05
Bucktail	Channel morphology monitoring site	104.6
Grass Valley Creek	Tributary	104.0
Trinity House Gulch	Tributary	103.7
Ponderosa Pool	Sand storage monitoring site	103.6
Tom Lang Pool	Sand storage monitoring site	102.8
Poker Bar Bridge	Bridge crossing the Trinity River	102.4
Reo Stott Pool	Sand storage monitoring site	102.0
Society Pool	Sand storage monitoring site	101.3
China Gulch	Tributary	100.95
Limekiln Gulch	Tributary	100.9
Limekiln Bank Rehabilitation	Bank rehabilitation project	100.2
Steel Bridge	Channel morphology monitoring site	99.2
Steel Bridge Pool	Sand storage monitoring site	99.0
Steel Bridge Bank Rehabilitation	Bank rehabilitation project	98.8
Trinity River blw Limekiln Gulch	USGS continuous streamflow gaging station (1981-1991)	98.3
Limekiln Cableway	Sediment transport monitoring site, HVT streamflow gaging station (1998-present)	98.3
MacIntyre Gulch	Tributary	96.95
Vitzthum Gulch	Tributary	96.3
Indian Creek	Tributary	95.3

Table 4.1 continued.

Name	Description	River Mile
Indian Creek near Douglas City	Sediment budget monitoring site, HVT continuous streamflow gaging station (1997-present)	95.3
Indian Creek	Channel morphology monitoring site	95.2
Weaver Creek nr Douglas City	USGS continuous streamflow gaging station (1959-1969)	93.8
Weaver Creek	Tributary	93.8
Hwy 299 Bridge	Bridge crossing the Trinity River	93.7
Reading Creek	Tributary	92.9
Douglas City Campground	Channel morphology monitoring site	92.8
Trinity River @ Douglas City	HVT continuous streamflow gaging station (1996-present)	92.2
Steiner Flat Bank Rehabilitation	Bank rehabilitation project	91.8
Steiner Flat	Channel morphology monitoring site	91.7
Lorenz Gulch	Tributary	89.3
Dutton Creek	Tributary	89.0
Browns Creek nr Douglas City	USGS continuous streamflow gaging station (1957-1967)	87.8
Browns Creek	Tributary	87.8
Trinity River near Douglas City	USGS continuous streamflow gaging station (1945-1951)	87.7
Maxwell Creek	Tributary	86.8
Dutch Creek	Tributary	86.3
Carr Creek	Tributary	85.3
Bell Gulch Bank Rehabilitation	Bank rehabilitation project	84.0
Bell Gulch	Tributary	84.0
Soldier Creek	Tributary	83.8
Deep Gulch Bank Rehabilitation	Bank rehabilitation project	82.2
Deep Gulch	Tributary	82.0
Sheridan Crk Bank Rehabilitation	Bank rehabilitation project	82.0
Sheridan Creek	Tributary	81.8
Upper Sky Ranch	Channel morphology monitoring site	81.6
Mill Creek	Tributary	81.2
Oregon Gulch	Tributary	80.9
Lower Sky Ranch	Channel morphology monitoring site	80.4
Dutch Creek Road Bridge	Bridge crossing the Trinity River	79.6
McKinney Creek	Tributary	79.6
Trinity River @ Junction City	HVT streamflow gaging station (1995-present)	79.6
Canyon Creek	Tributary	79.1
Canyon Creek	Channel morphology monitoring site	79.0
Jim Smith Bank Rehabilitation	Bank rehabilitation project	78.5
Conner Creek	Tributary	77.3
J & M Tackle	Channel morphology monitoring site	76.9
Wheel Gulch	Tributary	76.2
Valdor Gulch	Tributary	75.1
Pear Tree Gulch	Tributary	73.15
Pear Tree Bank Rehabilitation	Bank rehabilitation project	73.1
North Fork Trinity River	Tributary	72.4
North Fork Trinity River	DWR/USGS continuous streamflow gaging station (1912, 1913, 1957-1980)	72.4
Trinity River nr Burnt Ranch	USGS continuous streamflow gaging station (1932-40, 1957-present)	48.6
Trinity River at Hoopa	USGS continuous streamflow gaging station (1912, 1913, 1917, 1918, 1932-present)	12.4
Klamath River	Mouth of Trinity River	0.0

A historical perspective guides future restoration by identifying and understanding interrelationships between natural channel conditions and fishery production, and placing that understanding in the context of specific changes induced by the TRD. Managers can begin understanding the direct and indirect impacts of certain management actions to the river, how that impact propagated to the fishery, and then prescribing alternative management activities (restoration) to reverse those negative impacts.

tributaries, then later (from the early 1900's to the early 1950's) dredged most of the natural river channel, often from one valley wall to the other. Most floodplain and terrace features were destroyed, leaving extensive tailings. Although greatly increased sediment supply into the mainstem created chronic turbidity, salmon and steelhead populations were abundant. Physical evidence of pre-TRD channel conditions was uncovered from aerial photographs, interpretation of remnant channel features, and inspection of the USGS gaging station cableway cross-section records at Lewiston (RM 110.2) (McBain and Trush, 1997).

4.1.1 An Alluvial River Morphology

Although the river corridor had been greatly altered by gold mining, the Trinity River mainstem remained morphologically diverse. The Trinity River mainstem was, and still is, a mix of distinct channel morphologies, both alluvial and bedrock-controlled. Many channel reaches from Lewiston downstream to the North Fork Trinity River were alluvial, where the river had the capability of shaping its channelbed and banks. The pre-TRD Trinity River was resilient: Left to wander among the mine tailings, the mainstem reshaped portions of these tailing fields into a meandering channel typical of normally functioning alluvial rivers (Figures 4.2 and 4.3). The channel migrated or avulsed (rapid abandonment of channel to another location) across the valley floor over time, occupying all locations within the valley at some time. The mainstem had extensive floodplains and a meandering river corridor in its least confined reaches downstream from Dutch Creek (RM 86.3), as well as in partially confined channel reaches closer to Lewiston. Other reaches were variably influenced by depositional features composed mostly of cobbles or small boulders derived from bedrock outcrops.

An alluvial channel morphology is maintained in a "dynamic quasi-equilibrium" where sediment routed through the channel roughly equals the sediment supplied. Sediment is transported through or stored within the channel (dynamic), but the channel morphology fluctuates only narrowly over time (quasi-equilibrium). Knighton (1984) states, "no exact equilibrium is implied but rather a quasi-equilibrium manifests in the tendency of many rivers to develop an average behavior." Long- and short-term changes to sediment supply or flow regime initiate adjustments in channel morphology and the channel's "average behavior" (Lane, 1955). Although a dynamic quasi-equilibrium is not universal among rivers, the concept provides a useful baseline to evaluate alluvial processes before the TRD. In a nearby alluvial river, the South Fork Trinity River, alluvial features show signs of frequent, roughly annual mobilization, although overall morphology often appears unchanged between major floods. Pre-TRD aerial photographs of the mainstem Trinity River are similar.

Unregulated alluvial rivers are continually renewed through fluvial processes that shape and maintain the channelbed topography. A prevalent feature of low-gradient alluvial rivers, such as the Trinity River, is an alternate bar sequence. An alternate bar sequence consists of two point bars, opposite and longitudinally offset from one another, connected by a transverse bar (riffle) (Figures 4.4 and 4.5). Alternate bars, often referred to as "riffle-pool sequences", are composed of an

Figure 4.2. Trinity River near Junction City (RM 79.6) showing pre-TRD (1961) riparian communities at a discharge of 192 cfs.

aggradational lobe near the thalweg (the deepest part of the channel), a crossover (riffle), and an adjacent scour hole (pool). On a broader spatial scale, two alternate bars form a complete channel meander with a wavelength roughly equaling 9 to 11 bankfull channel widths (Leopold et al., 1964). Alternate bar features are readily apparent in pre-TRD aerial photographs (Figures 4.2, 4.3, and 4.4), even in reaches confined by bedrock valley walls such as the Trinity River near the confluence with Browns Creek (RM 87.8) (Figure 4.6). Typical pre-TRD meander wavelengths ranged from 2,500 feet to 4,000 feet, sinuosity values ranged from 1.0 to 1.2, and the radius of curvature for meanders varied on the basis of the degree of bedrock confinement.

During low flows the channel meanders through the alternating point bars, but during high flows the bars become submerged and the flow pattern straightens. During these periods of high energy, bedload is mostly transported across the face of these alternating point bars rather than along the thalweg. In contemporary unregulated alluvial rivers, alternate bar surfaces show signs of

Figure 4.3. Trinity River at Junction City (RM 79.6) in 1960 illustrating alternate point bar sequences at a discharge of 5,000 cfs.

frequent mobilization, but overall bar shape and elevation commonly appear unchanged in sequential aerial photographs between major floods.

Pre-TRD channel geometry was reconstructed by McBain and Trush (1997) using remnant floodplain/terrace features at Steiner Flat (RM 91.7) and at the USGS gaging station cross section at Lewiston (RM 110.2). Steiner Flat, a partially alluvial and partially confined channel reach that did not suffer major alteration due to gold mining, provided a reasonable site to assess pre-TRD channel morphology. On the basis of a reconstructed channel cross section, the pre-TRD bankfull channel width was estimated to be approximately 280 feet (Figure 4.7). At the Lewiston gaging station cableway cross section, the pre-TRD bankfull channel width was 250 feet and average bankfull depth was 7.5 feet (Figure 4.8).

Figure 4.4. Trinity River near Lewiston (RM 112.0) circa 1960, prior to the construction of TRD. Note alternate bar sequences and large floodplain.

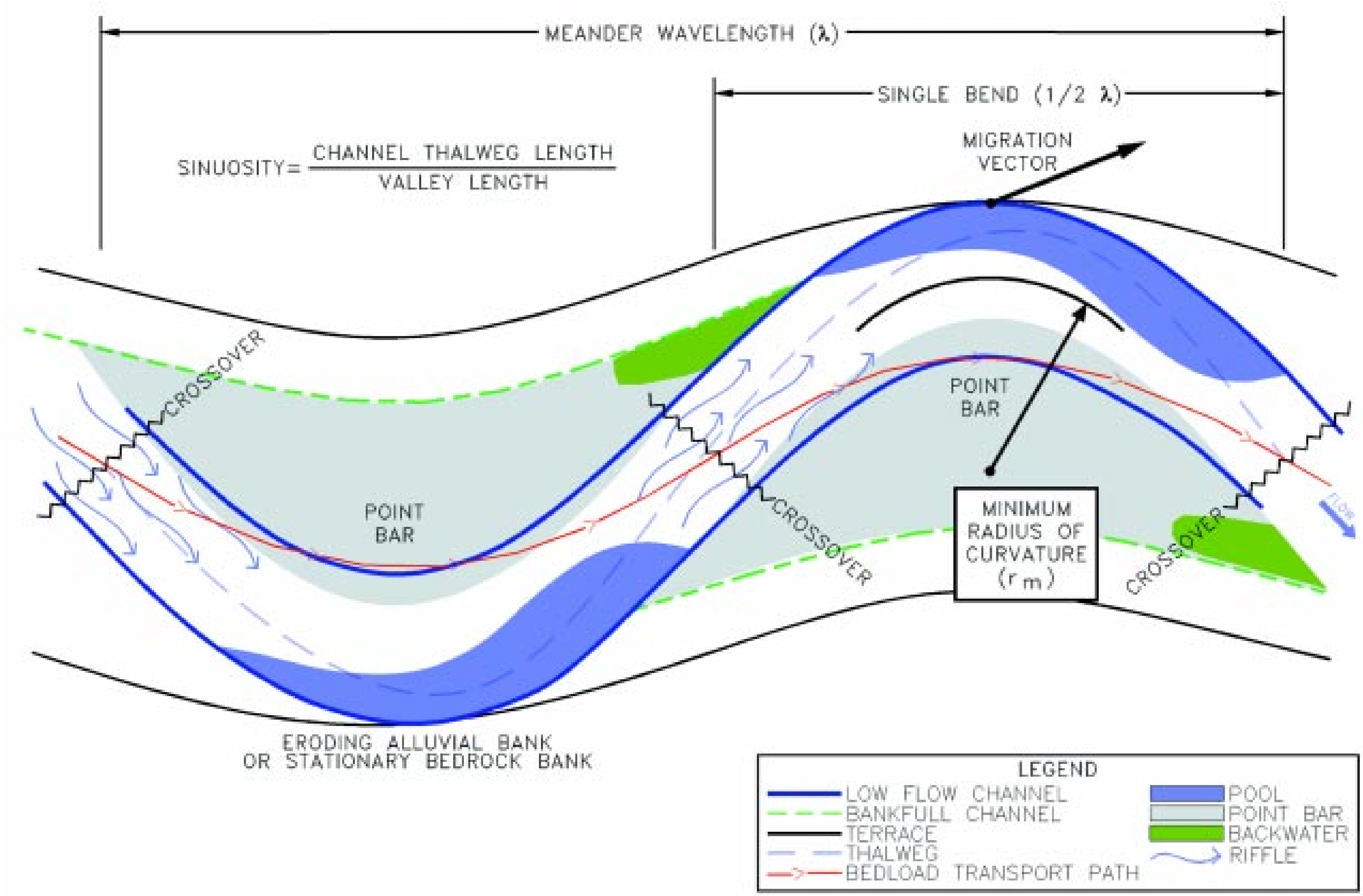


Figure 4.5. Idealized alternate bar sequence in an alluvial channel.

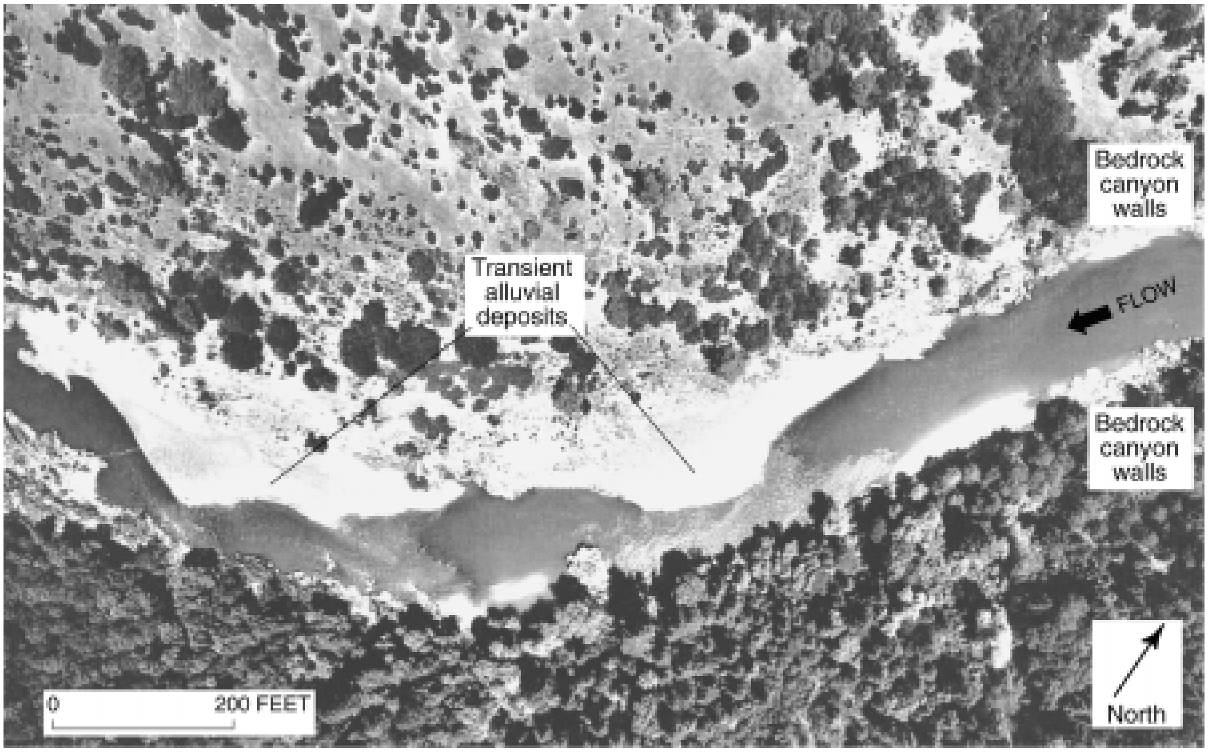


Figure 4.6. Trinity River at Browns Creek (RM 87.8) in 1961, illustrating alternate bar sequences at a discharge of 192 cfs.

4.1.2 Alternate Bars and Habitat

In the absence of extensive historical physical-habitat data, the role of alternate bars in creating habitat in contemporary alluvial river ecosystems was used as a guide to characterizing habitat availability in the historical mainstem. The topographic diversity of the pre-TRD channelbed surface generated diverse anadromous salmonid habitat at any given flow (Figure 4.9). For example, the steep riffle face of alternate bars, at winter and summer baseflows, provided widely varying water velocities and depths over short distances (a few feet). This hydraulic complexity created physical habitat for several age classes of juvenile salmonids. At typical baseflows, an alternate bar sequence on the mainstem provided adult holding areas, preferred spawning substrates, early-emergence slack water, and winter/summer juvenile rearing habitats (Figure 4.9). As baseflows varied within and among seasons, most if not all these habitats remained available although differing in proportion. Even in bedrock-influenced channel reaches, other macro-alluvial features, such as mid-channel bars and (or) point bars, generated similar habitat complexity. Associated features such as undercut banks, side channels, and backwater alcoves all contributed to a physical mosaic that collectively provided habitat for all salmonid freshwater life stages. In this report, alternate bars are considered to be discrete, physically definable units of salmonid habitat; this usage is similar to the traditional use of pools and riffles as habitat units by fisheries scientists.

The alternate bar morphology provides velocity, substrate, and topographical diversity over a wide range of flows, which is critical for providing high quality salmonid habitat.

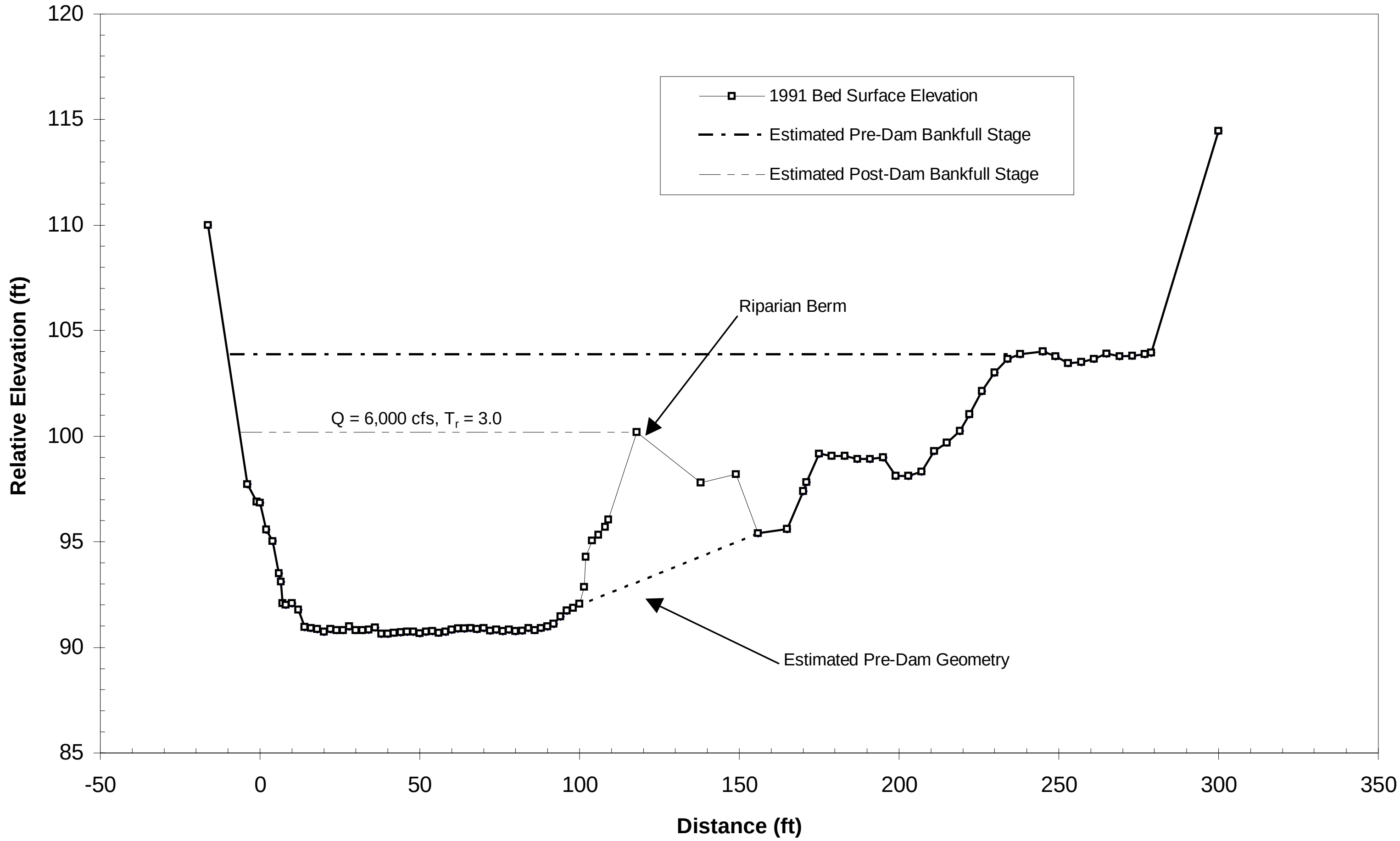


Figure 4.7. Change in Trinity River channel morphology and bankfull channel at Steiner Flat (RM 91.7), resulting from the TRD.

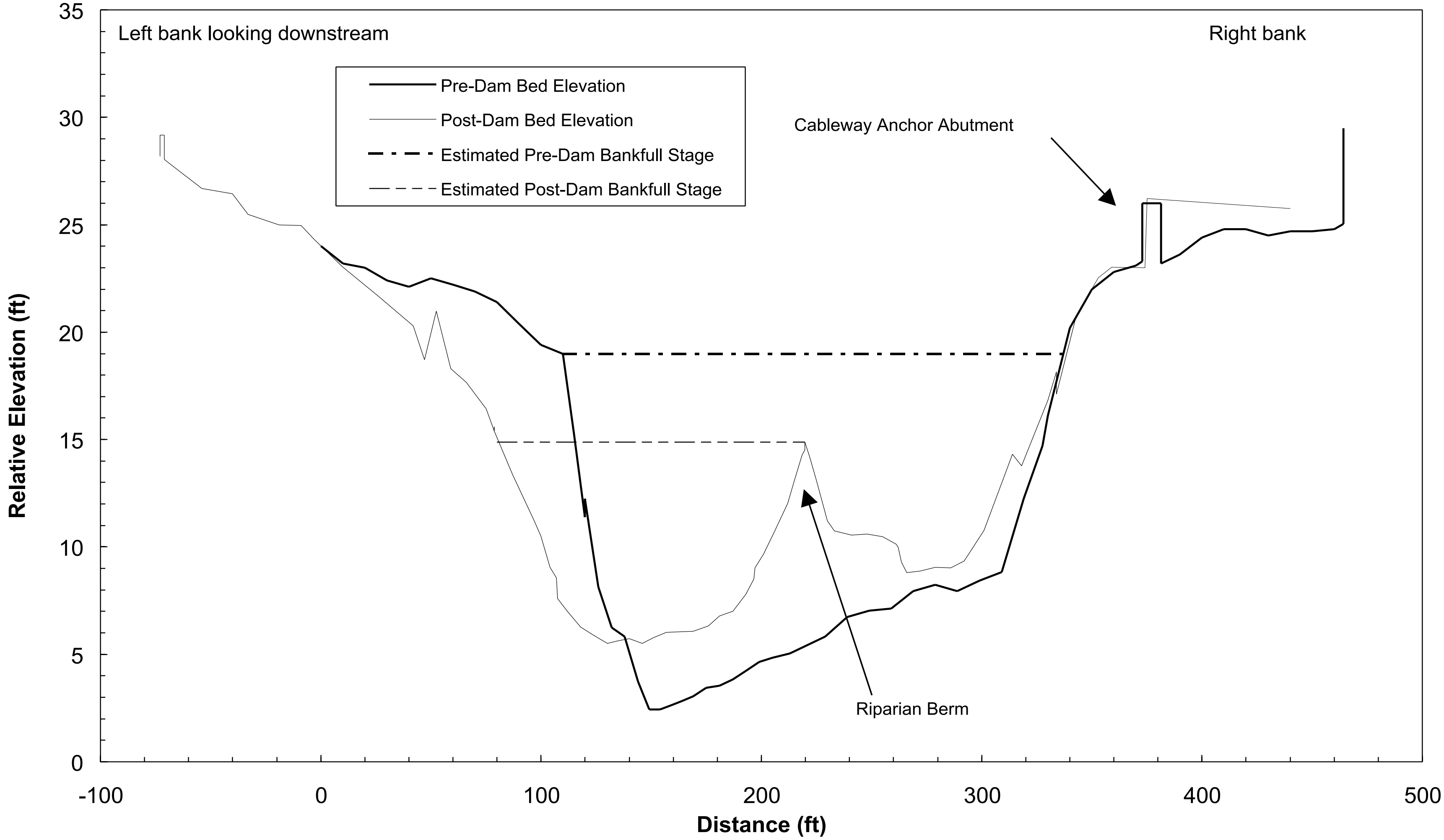


Figure 4.8. Change in Trinity River channel morphology and bankfull channel at the USGS gaging station at Lewiston (RM 110.2), resulting from the TRD.

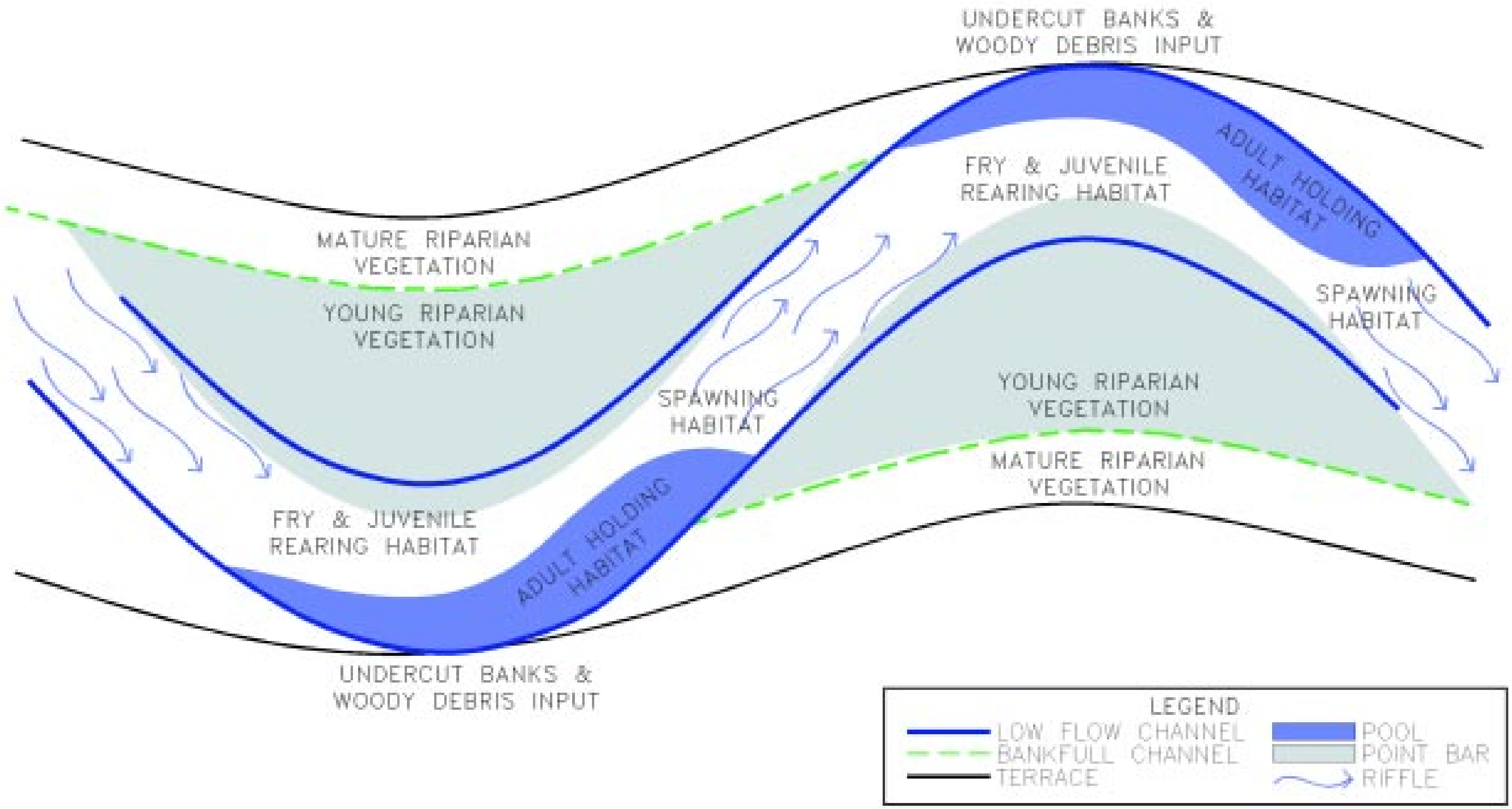


Figure 4.9. Salmonid habitats provided in an idealized alternate bar unit.

Alternate bar sequences provide additional ecological functions besides supporting anadromous salmonid habitat. A side channel commonly forms on the landward margin of an alternate bar and flows only during floods. The lower end of a side channel (the alcove) is usually deeper (having been scoured during large floods), and it provides amphibians refuge from high velocities during flooding, and thermal refuge during lower flows. Adult western pond turtles (*Clemmys marmorata*) forage and thermoregulate in and along pool and glide habitats of the main channel; smaller hatchlings and juveniles prefer backwater pools, shallow river margins, and side channels with vegetation (Reese, 1996). These habitats are typically created by alternate bar sequences. On the upstream end of alternate bars, a broad shallow area provides slightly warmer, slowly flowing water that attracts amphibians in the winter. The gently sloping, exposed flanks of alternate bars provide habitat for foothill yellow-legged frogs (*Rana boylii*) that deposit eggs in shallow, low-water-velocity areas on cobble bars with sparse vegetation (Lind et al., 1992). Early-successional riparian vegetation on mid- to upper surfaces of alternate bars provides habitat for many resident and migratory birds, including the willow flycatcher (*Empidonax trail*).

The variable flow regime was responsible for maintaining the integrity of alternate bar sequences and high quality salmonid habitat.

4.1.3 Annually Variable Flows Within Common Hydrograph Components

Annual flow variability is a key attribute of contemporary alluvial and mixed-alluvial rivers. Without flow variation, diverse physical processes cannot be sustained. Annual flows in the pre-TRD Trinity River mainstem varied considerably. During rain-on-snow storm events, instantaneous peak flows at Lewiston could exceed 70,000 cfs, peaking as high as 100,000 cfs. At the other extreme, late summer flows during droughts could drop below 100 cfs. Flows had predictable general trends, such as higher peak flows in wet years, lowest flows in late summer, and snowmelt runoff peaks during late spring and early summer, but other flow characteristics, such as the magnitude of peak flows and droughts, were extremely variable.

Seasonal patterns for daily average flow are identifiable as “hydrograph components” for Pacific Northwest rivers. Hydrograph components were identified for pre-TRD annual hydrographs (Figure 4.10) using the USGS Lewiston gaging data, other USGS gaging stations (Table 4.2), and Reclamation Trinity Lake inflow data (refer to McBain and Trush, 1997, for detail). Annual hydrograph components included summer baseflows, winter flood peaks, winter baseflows, snowmelt peak runoff, and snowmelt recession. Each varied in its duration, magnitude, frequency, and seasonal timing. Peak snowmelt runoff and high summer baseflows dominated annual hydrographs for high-elevation sub-basins, whereas lower sub-basins (downstream from Lewiston) generated more winter rainfall runoff and relatively low summer baseflows. Therefore, distinct differences in flow magnitude, duration, frequency, and timing in each hydrograph component occurred inter-annually and by basin location. Each hydrograph component (Figure 4.10) uniquely influenced the morphology and function of the mainstem channel, as well as the biological community.

4.1.3.1 Winter Floods

Large magnitude, short duration events typically occurred from mid-November to late January, with moderate magnitude events extending through late March. Peak flows exceeding 70,000 cfs have occurred three times since WY1912. Alternate bar mobilization, transport of the coarsest bed material through alternate bar sequences, tributary delta scour, floodplain/terrace deposition, potential meander changes (including channel avulsions), side channel creation, and significant channel migration

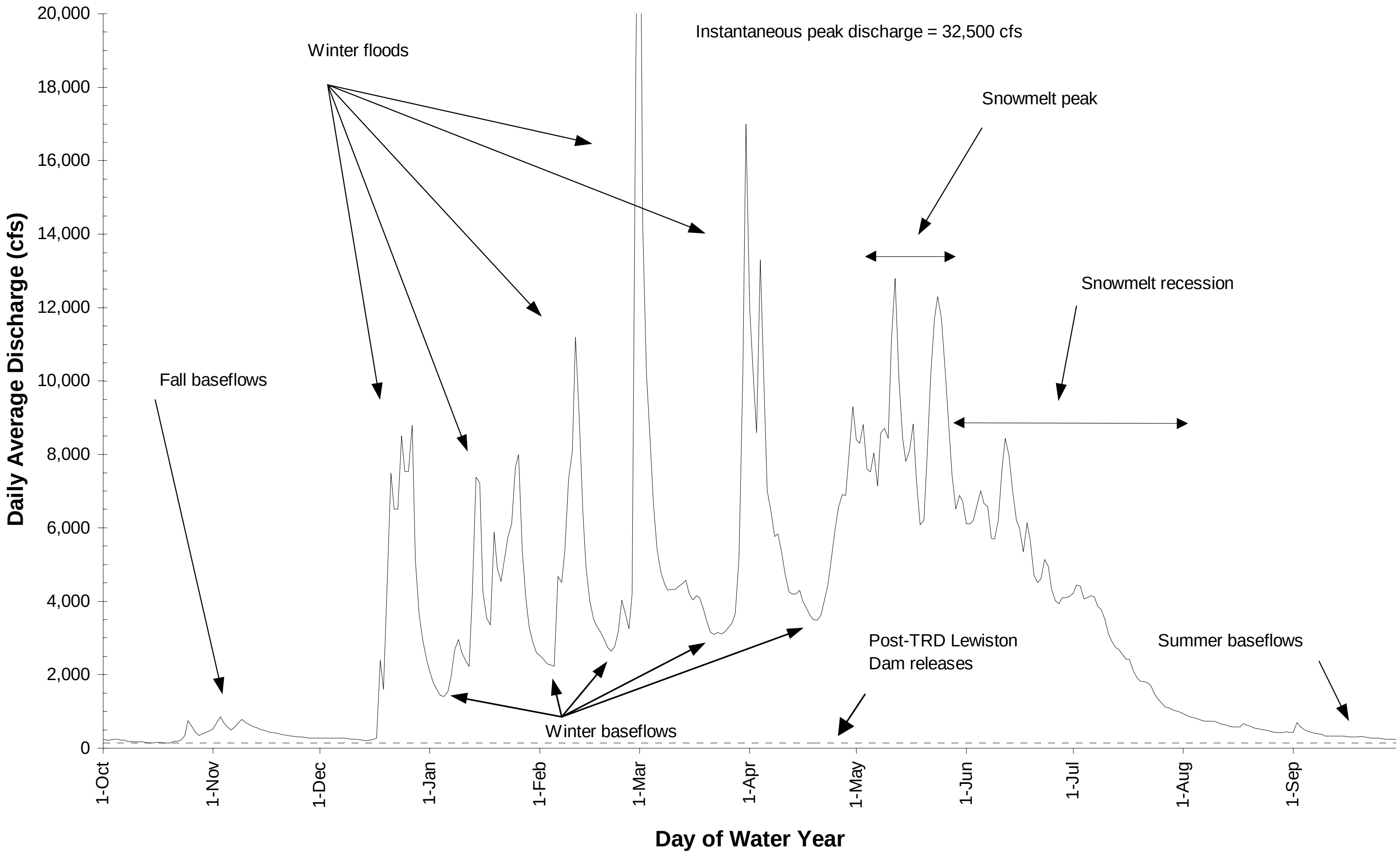


Figure 4.10. Trinity River at Lewiston streamflow hydrograph illustrating hydrograph components typical of a watershed dominated by rainfall and snowmelt runoff (Extremely Wet water year 1941).

Table 4.2. USGS streamflow gaging stations on the mainstem Trinity River and tributaries near the TRD.

Station Name	Drainage Area (mi^2)	USGS Station #	Period of Record Used	Number of Years
Trinity Lake near Lewiston	692	11525400	1961-1995	35
Trinity River @ Lewiston	719[b]	11525500	1912-60[a], 1961-95[b]	49, 35
Grass Valley Creek @ Fawn Lodge	30.8	11525600	1976-1995	20
Trinity River below Limekiln Gulch	812[c]	11525655	1981-1991[c]	11
Weaver Creek near Douglas City	48.4	11525800	1959-1969	11
Trinity River near Douglas City	933	11526000	1945-1951	7
Browns Creek near Douglas City	71.6	11525900	1957-1967	11
N.F. Trinity River @ Helena	151	11526500	1912,1913,1957-80	26
Trinity River near Burnt Ranch	1,438[d]	11527000	1932-40[a],1957-60[a],1961-95[d]	13,35
Trinity River at Hoopa	2,865[e]	11530000	1912,13,17,18,1932-60[a];1961-95[e]	33,35

[a] Pre-dam

[b] Post-dam, unregulated drainage area = 0.3 mi^2

[c] Post-dam, unregulated drainage area = 93.3 mi^2

[d] Post-dam, unregulated drainage area = 719 mi^2

[e] Post-dam, unregulated drainage area = 2,146 mi^2

were products of major winter floods. Moderate winter floods transported sand and intermediate volumes of coarse bed material, occasionally mobilized alternate bar surfaces, scoured the surfaces of spawning gravel deposits, and encouraged minimal channel migration.

4.1.3.2 Snowmelt Peak Runoff

The magnitude and timing of snowmelt peaks were largely a function of snow accumulation in the preceding winter. Extreme snowmelt peaks (generally rain-on-snow runoff) reached 26,000 cfs during wet years but typically ranged from 8,200 cfs to less than 2,000 cfs. The timing of the snowmelt peaks extended from late March to late June, with flows peaking later in wet years than dry. Snowmelt discharges produced flows that were generally smaller than winter floods, but of considerably longer duration. Moderate volumes of coarse bed material and large volumes of fine bed material were transported. Spawning-gravel deposits were rejuvenated, while scour and subsequent replacement of the channelbed surface only slightly reshaped alternate bars.

4.1.3.3 Snowmelt Recession

Snowmelt runoff could begin in late March and recede into late July in very wet years. In contrast, snowmelt runoff during dry years typically ended by mid-May. This component had only a minor direct influence on channel morphology by controlling areas of successful germination and seedling establishment. Off-channel wetlands also were influenced by the magnitude and timing of snowmelt recession into the summer.

4.1.3.4 Summer Baseflows

Generally, summer baseflows were established between mid- and late July. Summer baseflows typically ranged from 300 cfs during wetter years to less than 100 cfs during very dry years, although summer baseflows could drop to as low as 25 to 50 cfs. These baseflows indirectly influenced channel morphology by constraining woody riparian germination and seedling establishment to a narrow band above the baseflow stage height.

4.1.3.5 Winter Baseflows

The receding limbs of storm hydrographs and groundwater discharge supported relatively stable baseflows between winter storm events. Winter baseflows ranged from 3,000 cfs during wetter years to less than 500 cfs during drier years. Minor sand transport occurred.

Collectively, annual hydrograph components were responsible for alternate bars, riparian communities, and salmon populations. Big, infrequent floods were better at accomplishing some tasks such as mobilizing alternate bars, whereas smaller, more frequent floods produced smaller-scale benefits such as the scouring of seedlings. These variable flows created the spatial complexity underpinning salmon habitat and the riparian community in the pre-TRD mainstem.

4.1.4 Spatial and Temporal Diversity Sustained Salmon Populations

Salmon and steelhead populations persisted despite pervasive mining impacts because diverse habitat was available throughout many parts of the Trinity River Basin. Moffett and Smith (1950) describe habitat upstream from Lewiston (RM 110.9):

The 12 miles of river from Ramshorn Creek (RM 153) to Trinity Center (RM 141) traverse a broad valley into which many small tributary streams enter. The stream has a gradient of 58 ft. per mile [approximately one percent] and meanders through wooded and pasture lands wherever gold dredges have left the original terrain. Its channel is broad and gravelly with extensive riffles alternating with deep pools.

This river reach must have been prime salmonid habitat for spawning and rearing. Lower-gradient reaches (relative to this mean gradient) would have provided high-quality spawning and rearing habitat for chinook and coho salmon, while the structural complexity of higher-gradient, upstream reaches would have sustained prime rearing habitat for multiple age classes of coho and steelhead. Moffett and Smith (1950) concluded that most chinook salmon spawning grounds were within 69 miles of the mainstem channel from Trinity Center (RM 141.0) downstream to the North Fork Trinity River confluence

(RM 72.5; Figure 2.2). This mainstem segment has a low average gradient of 15 feet per mile (or approximately 0.3 percent).

Many adult salmon and steelhead migrated above Lewiston to hold over in summer and (or) to spawn in fall and winter. Spring-run chinook salmon would migrate from March through June, holding in deep, thermally stratified pools below Lewiston during the daytime. Moving upward at night, they would eventually reach the river above Lewiston, where the melting snowpack lowered water temperatures. There they would remain in pools for several months until the onset of spawning. Adult summer-run steelhead entered the Trinity River in June and early July. They held in the deep pools below Lewiston and were "common in the deep holes along the river below North Fork" (Moffett and Smith, 1950). These behavioral patterns spatially segregated the summer-run steelhead and spring-run chinook salmon. Later in the year, when the fall-run chinook salmon entered the river and remained primarily below Lewiston, the steelhead would enter the tributaries to spawn. Coho salmon entered the river after chinook salmon; winter-run steelhead followed and spawned in reaches farther upstream than those used by salmon. Adult Pacific lamprey migrated sporadically through the summer, gaining momentum into the winter months, then spawned during the snowmelt runoff period (Moffett and Smith, 1950). Therefore, during any month one or more anadromous fish species was migrating up the Trinity River mainstem, while redds were distributed throughout the mainstem and tributaries.

Spatial segregation and temporally variable life histories enhanced productivity and decreased intra- and inter-species competition. All salmonid fry utilize similar low-velocity habitat, but because the fry of each species emerged from redds at different times, this habitat was occupied at different times. For example, because habitat preferences change as fish grow, most chinook salmon fry would have emerged and grown to sizes that preferred deeper, higher velocity habitats by the time coho salmon fry emerged.

4.1.5 Unregulated Riverflow and Salmon at Lewiston

Anadromous salmonids used the upper basin differently because it looked and functioned differently than the mainstem below Lewiston. Moffett and Smith (1950) identified a key hydrologic dichotomy along the mainstem, roughly located near Lewiston:

The general runoff pattern over the entire Trinity drainage varies somewhat from that recorded at Lewiston. The spring runoff peak at Burnt Ranch (RM 49) occurs a month earlier than the peak at Lewiston. Inflow from many small tributaries which drain an area with little snow accumulation contributes most of the earlier runoff at that point. River flow at Hoopa, including the inflow from New River and the extensive South Fork drainage, reaches a spring runoff peak in March, two months earlier than the peak at Lewiston.

By virtue of its position in the watershed (at a transition point between high-elevation and low-elevation sub-basins), the mainstem near Lewiston possessed a dual hydrologic nature. The upper basin, including the Coffee Creek sub-basin, was heavily influenced by snowmelt runoff, although winter flows would peak briefly several times. From Coffee Creek (RM 145.5) downstream to Lewiston (RM 111.9), the basin was influenced significantly by winter storms and late-spring snowmelt runoff. The lower drainage basin, from Lewiston to Burnt Ranch, was dominated by winter storm runoff with relatively minor snowmelt runoff from a few tributaries (Rush Creek, Canyon Creek, and North Fork Trinity River). The future dam site at Lewiston would be located approximately at the Basin's transition from a snowmelt-dominated

> The flood hydrology downstream of Lewiston is dominated by rainfall runoff events, whereas upstream of Lewiston is equally dominated by rainfall and snowmelt runoff events. Unimpaired peak floods at Lewiston sometimes exceed 70,000 cfs to 100,000 cfs.

watershed to a winter-storm-dominated watershed. A sub-category of rainstorm events, the rain-on-snow event, was responsible for the largest floods throughout the basin.

This dual hydrologic nature had important consequences for salmonid life histories basinwide. Snowmelt runoff in late spring to early summer above Lewiston sustained mainstem flows below Lewiston; thus adult and juvenile fish in the mainstem below Lewiston depended on the timing and duration of flows originating above Lewiston. However, the rapid decline in snowmelt runoff typically decreased discharges to well below 1,000 cfs (or even 500 cfs) by mid-July at Lewiston (Appendix F). Even snowmelt flows could not keep the mainstem below Lewiston hospitable to salmonids throughout the summer.

From 1942 to 1946, Moffett and Smith (1950) frequently monitored water temperatures and sampled the mainstem near the future dam site at Lewiston for anadromous salmonids (Figure 4.11 — thermographs reproduced from Moffett and Smith, 1950). These temperature findings are best summarized by the authors (p. 9):

Trinity River [at Lewiston] is warmest during July and August when spring and summer salmon are holding over in the main river. The maximum water temperatures and dates of occurrence for years of record are as follows: 78°F on August 13, 1943; 81°F on July 24 and 27, 1944; and 83°F on July 27, 1945. Temperature records were not complete enough in 1946 to show the highest temperature with certainty, but a high of 80.5°F was reached on July 22, 1946. The maximum temperature recorded for 1943 may not be the true peak temperature for that year, as it was taken from partial records made during August and September. A temperature of 80°F or higher was recorded on 9 days during the summer of 1944 and 27 days during the summer of 1945. As a result of experience gained at Deer Creek Station on the Sacramento River . . . , 80°F is considered lethal or near lethal for king salmon. The same species is able to survive when surface temperatures are above 80°F in the Trinity River by remaining in the cooler waters of deep holes along the river. In August 1944, water at depths over 8 feet in one of these large holes was 7°F cooler than surface water.

Moffett and Smith documented water temperatures at Junction City that exceeded 80°F for 32 days in 1945 beginning in late July. The mainstem downstream from Lewiston was a stressful environment for juvenile salmonids or holding adults after mid-July. Salmonids incubated and reared above Lewiston in cooler waters (Moffett and Smith did not report monitoring temperature upstream from Lewiston) had to cope with and (or) avoid these near-lethal (if not lethal) mid-summer water temperatures during their seaward migration. Most species chose avoidance. Older age classes of juvenile steelhead outmigrated well before water temperatures rapidly increased, as observed by Moffett and Smith (1950) near Lewiston:

During extended winter dry periods when the river is low and clear, groups of several hundred steelhead trout 6 to 8 inches in length can be seen slowly drifting downstream. The size of these fish would indicate that they were in their second year or third year of life. These schools migrate down the center of the river hovering close to the bottom....

Outmigration was timed to coincide with the periods when the pre-TRD river temperatures were lowered by snowmelt from the upper watershed. Juvenile chinook salmon outmigrated from Lewiston in late spring and early summer, prior to rapid temperature increases and low summer flows (Moffett and Smith, 1950; Figure 4.12). Most chinook salmon (approximately 90 percent) passed Lewiston by late June. Melting snow provided suitably cool temperatures and relatively large flows that aided downstream migration of smolts by reducing their travel time to the ocean. Combined, the large flows and suitable water temperatures would have given most fish sufficient time to reach the Klamath estuary before mainstem temperatures became unsuitable

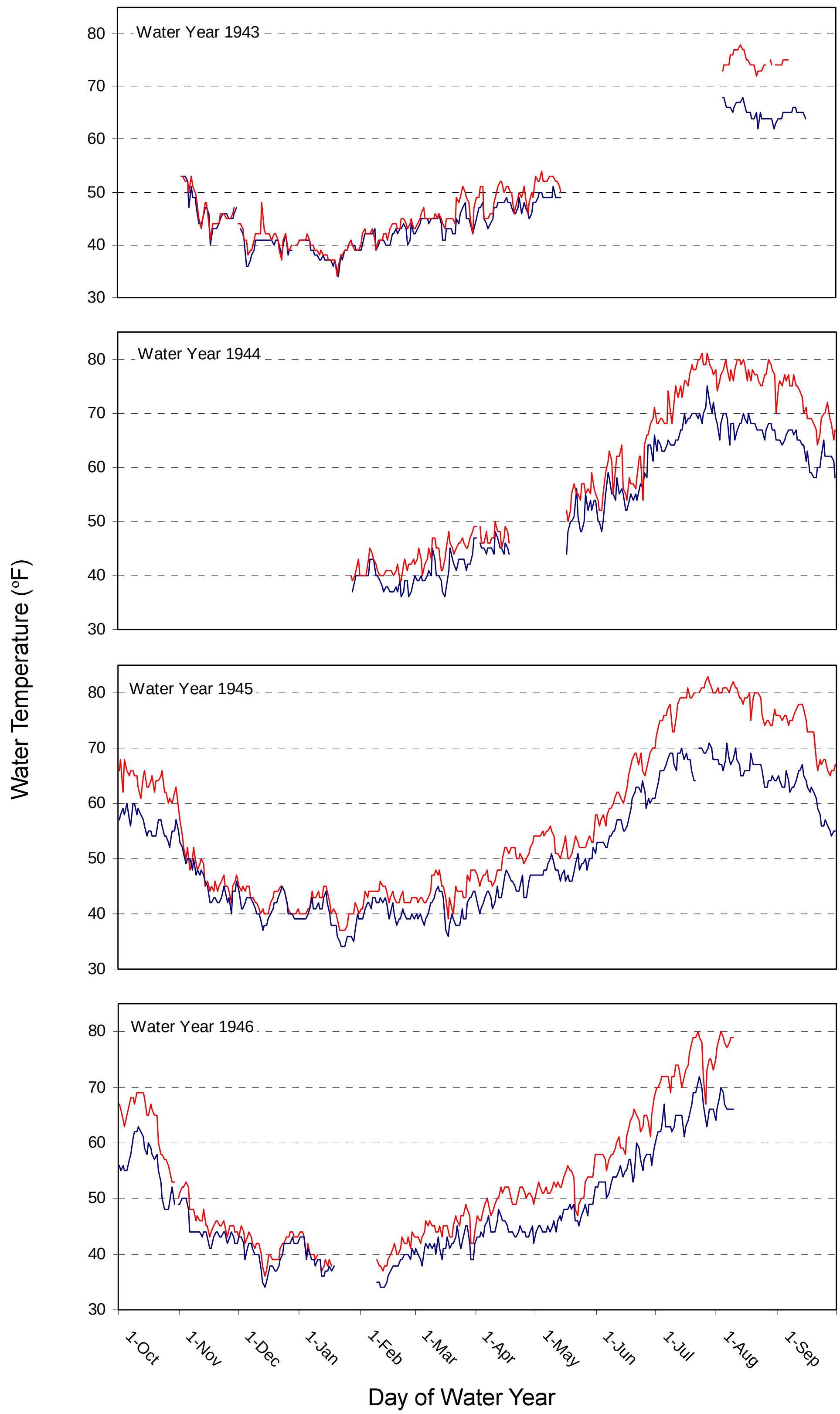


Figure 4.11. Maximum and minimum Trinity River water temperatures at Lewiston for water years 1941-1946. Data collected by Moffett and Smith (1950).

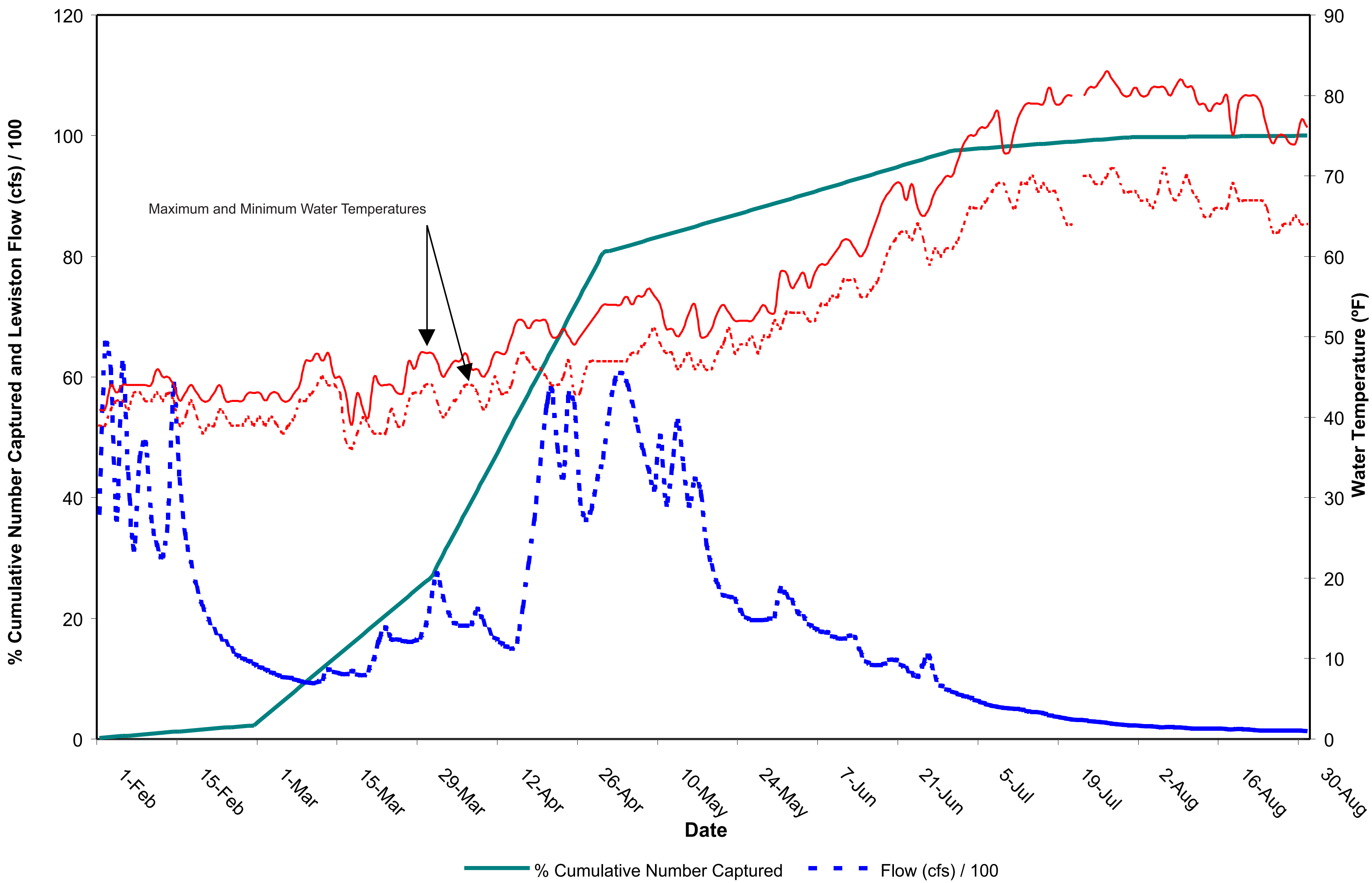


Figure 4.12. Water temperatures, flows, and chinook presmolt outmigration on the Trinity River near Lewiston, during the spring and summer of 1945. Data collected by Moffett and Smith (1950).

(>68°F for chinook salmon smolts). Those migrating later could have survived inhospitable water temperatures by migrating between thermal refugia, such as deep pools, seeps, springs, and some tributary deltas, or remaining in the cooler upper watershed until fall, when temperatures were cooler in the lower watershed.

4.1.6 Woody Riparian Plant Characteristics

With the exception of early aerial photographs, there are no descriptions of historical riparian communities; therefore, pre-TRD conditions were inferred by combining an interpretation of aerial photographs with observations of regional unregulated streams (e.g., South Fork Trinity River). Air photographs taken in 1960 and 1961 show sparsely vegetated point bars (Figures 4.2, 4.3, 4.4, and 4.6). Willow patches were interspersed on upper portions of the bars and along margins of dredger tailings. Plants on alternate bar surfaces were annual herbs, grasses, and pioneer woody species such as willows (*Salix spp.*) (Table 4.3). Other riparian trees, including white alder (*Alnus rhombifolia*), black cottonwood (*Populus balsamifera ssp. trichocarpa*), and Fremont cottonwood (*Populus fremontii*), were well established on developing floodplains, low terraces, and oxbows (abandoned channel bends).

Frequent pre-TRD floods discouraged riparian vegetation from colonizing bars near the low flow channel, forcing vegetation to establish on floodplains, backwater channels, sloughs, and protected rocky slopes.

Woody riparian plant species are sensitive to intra- and inter-annual variation in flow. Viable seeds are released by most woody riparian species during the snowmelt runoff period (Figure 4.13). Two notable exceptions are white alder, releasing seeds in the fall, and shiny willow (*S. exigua*), releasing seeds from late spring through August. Floodplain and alternate bar surfaces, freshly deposited and scoured by snowmelt floods, were ideal germination sites, but long-term survival on mobile alternate bar surfaces was unusual.

Woody riparian vegetation did not completely colonize alternate bars for several reasons. In most wet years, flows during the snowmelt recession limb continued into July, inundating most alternate bar surfaces throughout much of the seed-release period. Seedlings can not germinate if the substrate is inundated. Exposed bar surfaces that could support successful germination were present primarily during drier years.

Newly germinated seedlings were vulnerable to scour by the following winter's high flows. Mobilization of the channelbed surface layer should have scoured out and (or) winnowed young seedlings rooted as deep, or slightly deeper, than the channelbed's surface layer. However, the entire channelbed surface was not uniformly susceptible to mobilization. Surfaces higher on alternate bars and on the floodplains required greater magnitude floods for bed surface mobilization. A range of threshold flow magnitudes would have been necessary to prevent seedling survival throughout alternate bar sequences. Mainstem flows capable of mobilizing at least a portion of the channelbed surface layer were commonly generated by winter floods and larger snowmelt runoff peaks.

If two or three consecutive drier years occurred, germination was favored. A small percentage of young seedlings often escaped scour for 2 years or longer, at which time they became securely rooted deeper than the surface layer. Occasionally, seedling establishment was widespread. Larger but less frequent floods would scour deeply rooted seedlings. Flood peaks occurring every 3 to 5 years could scour alternate bar sequences significantly deeper than their surface layers.

Table 4.3. Common woody riparian plant species along the Trinity River mainstem from Lewiston Dam (RM 111.9) downstream to the North Fork Trinity River confluence (RM 72.4).

Species	Common Name
Salix lucida ssp. lasiandra	Shining willow
Salix lasiolepis	Arroyo willow
Salix laevigata	Red willow
Salix melanopsis	Dusky willow
Salix exigua	Narrow-leaf willow
Alnus rhombifolia	White alder
Fraxinus latifolia	Oregon ash
Populus balsamifera ssp. trichocarpa	Black cottonwood
Populus fremontii	Fremont cottonwood

Maturing trees tended to establish in stands. As a stand matured, the hydraulic forces of flood flows were modified. Often hydraulic modification was so complete that the channel's surface beneath a stand experienced aggradation rather than scour. However, a stand could be undercut by lateral bank migration or isolated from the active mainstem channel by bank avulsion. Only large, relatively rare floods with recurrences of 10 to 30 years were capable of large-scale bank erosion or avulsion. These floods would have been generated by the more intense winter flows, or possibly rain-on-snow events.

4.2 Immediate Effects of Dam Construction on Basinwide Salmonid Habitat and the River Ecosystem

Completion of Trinity and Lewiston Dams in 1964 had three immediate effects on the river ecosystem. First, Lewiston Dam blocked all anadromous salmonid migration, eliminating all rearing and spawning habitat upstream. Second, bedload transport from 719 square miles of the Trinity River Basin above the dams was eliminated. A third immediate effect was major flow diversion from the Trinity River Basin to the Sacramento River Basin. All three effects would have severe consequences.

4.2.1 Loss of Habitat and Its Consequences

More than 100 miles of anadromous salmonid habitat above Lewiston were lost (USFWS, 1994). For chinook salmon, Moffett and Smith (1950, p.4) described this lost habitat:

Almost without exception, Trinity River salmon migrating above the South Fork spawn in the 72 miles of river between the North Fork and Ramshorn Creek. In addition to the main river, three tributaries are used by spawning salmon. A dam at the Lewiston site would cut off 35 miles of the main river and all of Stuart Fork [Figure 2.2], the most important spawning tributary. The salmon would be blocked from approximately 50 percent of their natural spawning grounds in the upper Trinity.

Salmonid populations were now abruptly forced to rely on the mainstem below Lewiston Dam in new ways. Dam construction compressed the distribution and

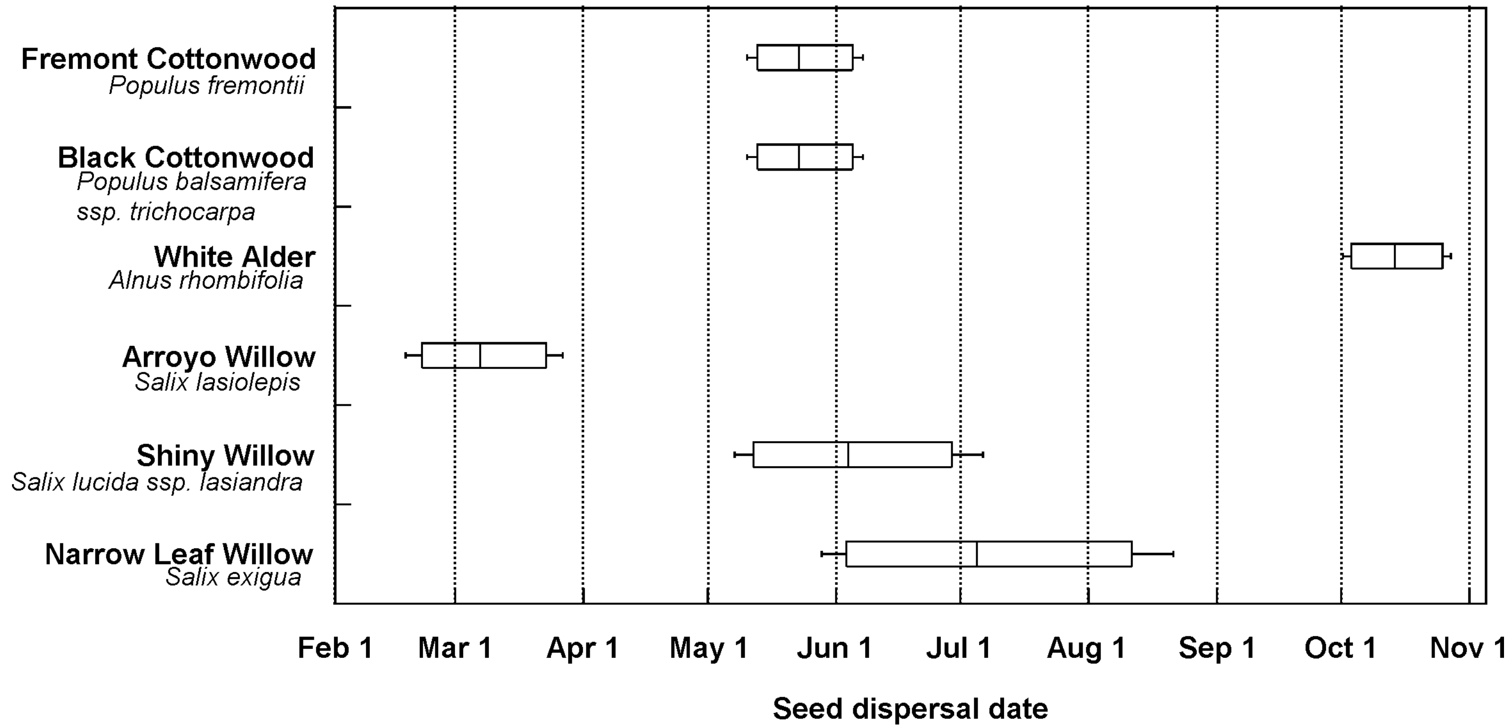


Figure 4.13. Woody riparian seed dispersal timing for six common species. Each box displays the length of time by which 90 percent of all seeds are dispersed. Median dispersal dates are represented by a vertical line through the box. Whiskers at either end of the box indicate the earliest and latest 5 percent of seed dispersal. White alder continues to drop seeds retained in the woody cone throughout winter and early spring, although more than 80 percent of the seeds are dropped during the initial seed dispersal period when female cones open.

seasonal timing of habitat use among species that were once segregated temporally and spatially. Spring-run chinook salmon that formerly held and spawned primarily above Lewiston (Moffett and Smith, 1950) were now forced to hold and spawn below Lewiston Dam. Summer-run steelhead historically held in these lower pools and now had to compete with spring-run chinook salmon.

> Completion of the TRD: blocked salmonid access to the upper watershed, blocked all coarse sediment supply from the upper watershed, and greatly reduced the volume and magnitude of flows to the lower Trinity River.

Comparison of pre- and post-TRD descriptions of adult chinook salmon migration and spawning patterns indicates a compaction of spawning timing. Moffett and Smith (1950) describe three distinct spawning runs of chinook salmon that passed Lewiston on the Trinity River in 1944 and 1945, but Leidy and Leidy (1984) describe only two distinct chinook salmon runs: spring and fall. Direct comparison of these two reports is problematic, however, because Moffett and Smith (1950) describe spawning runs that passed Lewiston whereas Leidy and Leidy (1984) describe timing below Lewiston. Although Trinity River salmonids continue to have long spawning periods, there is less segregation between species and between races of the same species than prior to dam construction.

The mainstem below Lewiston had been an inhospitable environment in late summer. If the Trinity River had maintained its pre-TRD annual temperature regime downstream, fry emerging from areas below the dams would have had no choice but to leave the mainstem by mid- to late-July or seek very limited thermal refuge. As Moffett and Smith (1950) note, many returning adult steelhead had spent 2 or more years in freshwater prior to smolting; large smolts have a considerably improved prospect of surviving to adulthood in the ocean. Before the TRD, these older juveniles could rear in the cooler upper watershed and tributaries, then avoid the warm mainstem below Lewiston by outmigrating during the winter baseflows, snowmelt peak, and (or) snowmelt recession hydrograph components. Therefore, prior to the TRD, steelhead that spawned in the mainstem below Lewiston may have been poor contributors to the basin's next cohort. Coho salmon juveniles would have been similarly affected because of their overwintering requirement. The original claim that approximately half the basin's anadromous salmonid habitat was eliminated by the TRD is probably a significant underestimate.

> The upper Trinity River watershed provided important rearing habitat and adequate summer water temperatures. Blocking the upper Trinity River watershed from salmonid access forced the remaining anadromous reaches to assume the habitat role historically provided by the upper watershed.

4.2.2 Loss of Suitable Coarse Bed Material

An alluvial river can function appropriately only if continuously supplied with bed material. Construction of Trinity Dam stopped all bedload supply to the lower reaches. Balancing the sediment budget, as one prerequisite for sustaining a dynamic river channel morphology and salmonid habitat, was ignored amid the early-1960's promises that salmon populations would thrive and possibly improve under TRD operating policies (Trinity Journal, 1952).

As occasional high-flow releases scoured the channelbed and mobilized bed material downstream without replacement from upstream, the net effect was channel degradation. In coarser river channels, as is the Trinity River mainstem, occasional high- flow releases transport only the finer fraction of the channelbed, leaving the coarser particles behind. Eventually, the channelbed coarsens until it virtually immobilizes. The extent of channel degradation will depend on channelbed particle-size composition and the relationship between the magnitude, duration, and frequency of flow releases.

In the mainstem below Lewiston, the already coarse channelbed coarsened even more without significant channel downcutting. Prominent alluvial features, such as alternating bars, disappeared or were immobilized. The post-TRD flow reductions also caused spatial changes in sediment-transport processes. The absence of high mainstem flows permitted tributary-derived sediments to accumulate and form aggrading deltas at the tributary confluences. Additionally, larger particles that were commonly transported during pre-TRD floods were no longer mobilized by the post-TRD flow regime, such that only the finer gravels and sands were transported downstream. In many reaches, a veneer of these finer particles is evident on top of the coarser, pre-TRD bed surface.

Coarse bed material forms the channel and habitat within the channel. Loss of coarse bed material from the upper watershed, combined with riparian encroachment of alluvial deposits downstream of Lewiston, greatly decreased the quantity and quality of remaining habitat.

Salmon-spawning habitat is as dynamic as the river and watershed that creates and maintains it. Gravel deposits in the tails of pools and runs, often preferred spawning habitat, are subject to frequent scour. As hatchery operators are aware, salmon eggs are extremely sensitive to handling during early development and can be killed simply by vibration. For salmon to have chosen to spawn in gravel subject to the forces of channelbed scour must mean that the risk is offset by the benefits of frequent gravel mobilization and sorting. Frequent cleansing of fine sediments from sorted gravels is advantageous to egg vitality and emergence success. High-quality spawning habitat requires frequent mobilization and gravel replenishment.

Moffett and Smith (1950) failed to link their spawning-flow recommendations for the future TRD, (which were based on observed depth and velocity preferences of spawning salmon), to the higher sediment transport flows required to shape and maintain the spawning habitat. The habitat they quantified in the 1940's would not have existed unless the flow-related physical processes that shaped the alluvial deposits and supplied the gravel also existed. Their recommended daily average flow release of 150 cfs could not accommodate these processes nor supply the necessary gravel. Spawning-habitat degradation began the first year of the TRD's bedload blockage.

4.2.3 Loss of Flow

Trinity River hydrology dramatically changed when the TRD regulated instream flows. The USGS has collected annual river discharge at Lewiston (USGS Sta. No. 11-525500), just downstream from Lewiston Dam (Figure 4.1), beginning in WY1912 (Table 4.2). Since WY1964, this gage has monitored flows regulated by the TRD. By monitoring stage height in Trinity Lake, Reclamation has been able to estimate annual unregulated flow since TRD operations began. Therefore, by combining gaging records for the USGS Lewiston gage before TRD operations (WY1961) with Reclamation stage height monitoring, an 84-year record of unregulated annual flows was reconstructed. Mean annual (October 1 through September 30) unregulated water yield from the Trinity River Basin (WY1912 to WY1995) above Lewiston is 1,249 TAF, ranging from a low of 234 TAF in WY1977 to a high of 2,893 TAF in WY1983 (Table 4.4).

Since TRD operations began, annual instream releases to the Trinity River downstream from Lewiston Dam, including flood control releases above the 120.5 TAF fishery flows, ranged from 119 TAF in WY1977 to 1,291 TAF in WY1983 with an overall mean of 325 TAF. Post-TRD instream releases to the Trinity River ranged from 8 percent of the unregulated annual yield in WY1965 to 63 percent in WY1994. From WY1961 to WY1995,

Table 4.4. Trinity River watershed pre- and post-TRD annual water yield (af) and percent instream release. (Yield = volume flowing past Lewiston (pre-TRD) or post-TRD water inflow to Trinity Lake, Release = annual volume released to the Trinity River (post-TRD), % Instream = percentage of inflow released to Trinity River (post-TRD)). Full TRD operations began in 1964.

WY	Yield (AF)	WY	Yield (AF)	WY	Release (AF)	Yield (AF)	% Instream
1912	1,029,000	1946	1,415,000	1961	223,000	995,000	18
1913	1,074,000	1947	732,300	1962	157,200	885,800	15
1914	2,028,000	1948	1,205,000	1963	862,500	734,500	54
1915	1,506,000	1949	1,090,000	1964	158,800	617,200	20
1916	2,154,000	1950	853,700	1965	129,100	1,666,700	8
1917	652,500	1951	1,610,000	1966	150,900	1,320,800	11
1918	602,400	1952	1,817,000	1967	238,500	1,638,000	15
1919	1,151,000	1953	1,612,000	1968	129,300	1,060,900	12
1920	408,400	1954	1,595,000	1969	155,800	1,765,600	9
1921	1,795,000	1955	734,800	1970	213,700	1,585,600	13
1922	783,400	1956	2,027,000	1971	179,900	1,695,200	11
1923	686,000	1957	1,083,000	1972	123,000	1,193,600	10
1924	266,300	1958	2,694,000	1973	132,800	1,413,000	9
1925	1,499,000	1959	1,042,000	1974	705,600	2,675,800	26
1926	808,900	1960	1,025,000	1975	275,400	1,415,000	19
1927	1,826,000	1961	TRD	1976	126,600	704,800	18
1928	1,058,000		construction	1977	119,400	233,800	51
1929	528,600		began;	1978	178,100	2,038,800	9
1930	814,400			1979	225,100	867,800	26
1931	402,200			1980	322,600	1,476,800	22
1932	720,800			1981	282,400	884,700	32
1933	803,600			1982	468,100	2,002,000	23
1934	683,000			1983	1,291,300	2,893,300	45
1935	965,600			1984	569,700	1,535,700	37
1936	1,025,000			1985	250,700	861,200	29
1937	999,300			1986	495,200	1,596,700	31
1938	2,105,000			1987	309,200	898,900	34
1939	573,300			1988	255,700	977,500	26
1940	1,613,000			1989	329,900	1,074,000	31
1941	2,547,000			1990	233,100	732,100	32
1942	1,804,000			1991	270,800	503,800	54
1943	1,108,000			1992	354,900	936,400	38
1944	654,100			1993	367,600	1,766,200	21
1945	1,048,000			1994	355,400	568,200	63

annual instream releases represented 28 percent of the unregulated annual water yield of the Trinity River above Lewiston. Prior to the 1981 Secretarial Decision (Chapter 2), this annual percentage averaged 20 percent. After 1981, an annual average of 35 percent of the unregulated yield was released below Lewiston (Table 4.4). The current annual instream flow volume of 340 TAF is equal to the third driest year at Lewiston in the 84-year period of record, which indicates the Trinity River has largely experienced severe drought conditions since TRD operations began.

For the first 20 years of operation, the TRD exported 80% to 90% of the water yield at Lewiston to the Sacramento River Basin.

4.3 Cumulative Downstream Effects of the Trinity River Division

Direct effects of the TRD triggered rapid, cumulative downstream effects. By the mid-1970's, resource agencies and the public sensed that "something" needed to be done (Sill, 1973; Hubbel, 1973).

4.3.1 Post-TRD Hydrologic Changes in the Mainstem

To identify gross changes, annual maximum flood frequencies and daily average flow duration were compared for the unregulated (pre-TRD) and the regulated (post-TRD) mainstem (McBain and Trush, 1997). Hydrologic data for comparing pre-TRD conditions to post-TRD conditions included (1) instantaneous peak discharges (for annual maximum flood frequency analysis) and (2) daily average discharge (for plotting annual hydrographs) obtained from various USGS gaging stations (Table 4.2).

4.3.1.1 Annual Maximum Peak Discharges

Pre-TRD maximum flood flows at Lewiston were highly variable, ranging from a low of 3,060 cfs in WY1920 to a high of 71,600 cfs in WY1956 (Figure 4.14). Flood magnitude increased rapidly downstream as larger unregulated tributaries (e.g., North and South Fork Trinity River, New River) contributed to flood flows at Burnt Ranch and Hoopa (Figures 4.14 to 4.16, Table 4.5).

The TRD substantially altered flood magnitudes at the Lewiston and Burnt Ranch gages, with the post-TRD 1.5 year flood having 10 percent of the pre-TRD flood magnitude at Lewiston and 50 percent at Burnt Ranch (Table 4.5). The TRD has minimal influence on the annual maximum flood magnitude at Hoopa because of flood contributions of the South Fork Trinity River and the New River, both entering the mainstem below Burnt Ranch (Figure 2.1). The Lewiston gage provides post-TRD flood-frequency estimates only immediately below Lewiston Dam, but not farther downstream because of tributary floods. Large floods still occur downstream from Browns Creek (RM 87.8), but flow magnitudes were nearly always less than 50 percent of the pre-TRD magnitude and were less frequent (refer to McBain and Trush, 1997, for details).

4.3.1.2 Mainstem Flow-Duration Curves

For both the pre-TRD record (pre-WY1960) and post-TRD record (WY1961 to WY1993), flow-duration curves were generated for Lewiston (RM 110.9), Burnt Ranch (RM 48.6), and Hoopa (RM 12.4) (Figures 4.17 to 4.19). Operation of the TRD reduced flow durations at Lewiston by nearly an order of magnitude at the 10 to 30 percent exceedence probabilities (pre-TRD 4,000 cfs to 1,900 cfs; post-TRD 550 cfs to 310 cfs) (Figure 4.17).

The 1.5 year flood, largely responsible for channel formation, channel sizing, and mobilizing coarse bed material, was reduced from 10,700 cfs to 1,070 cfs. The latter value is incapable of mobilizing particles greater than sand, such that coarse sediment transport nearly ceased to occur.

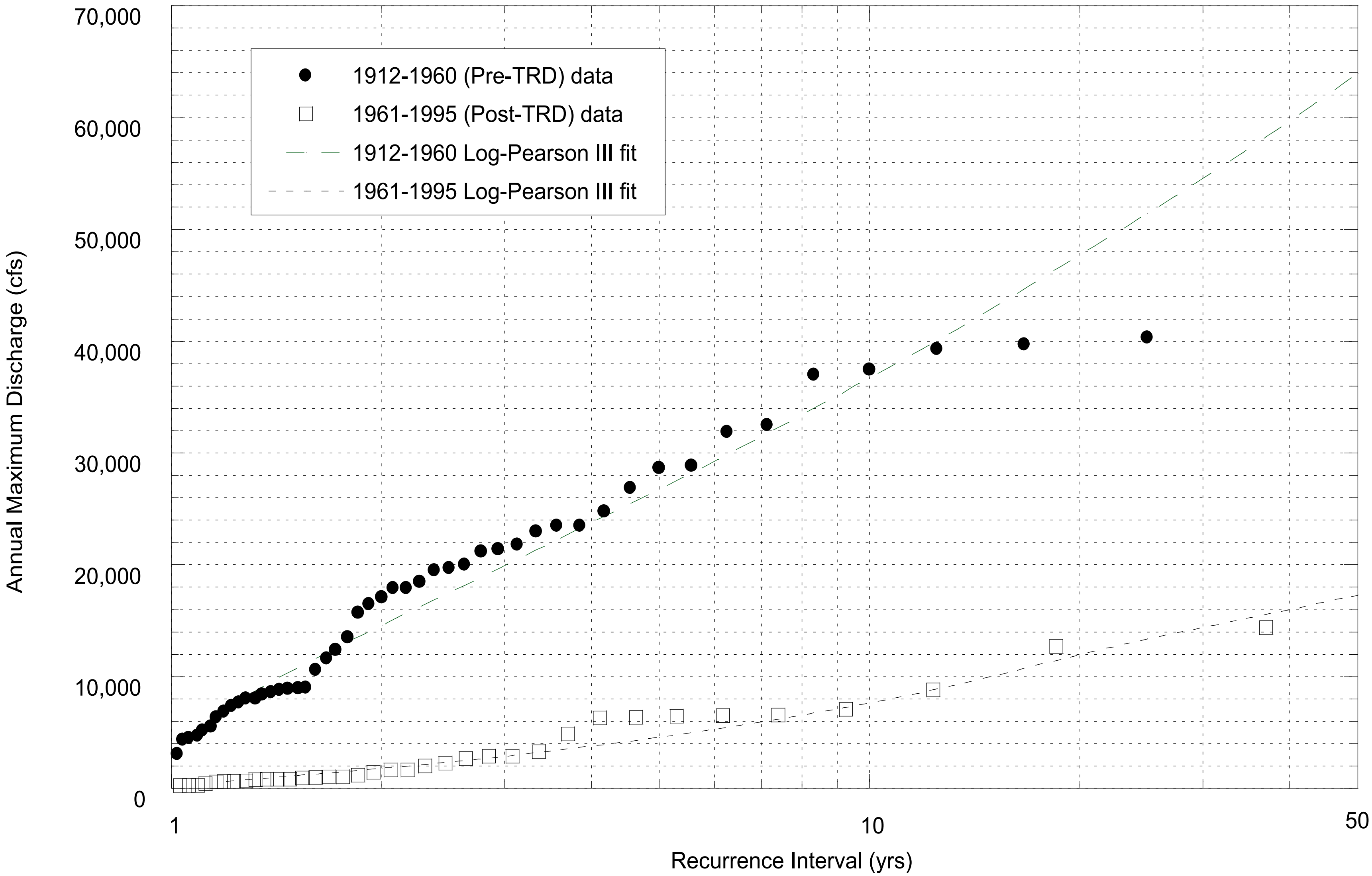


Figure 4.14. Trinity River flood-frequency curves at Lewiston (RM 110.9) before (1912-1960) and after (1961-1995) construction of TRD.

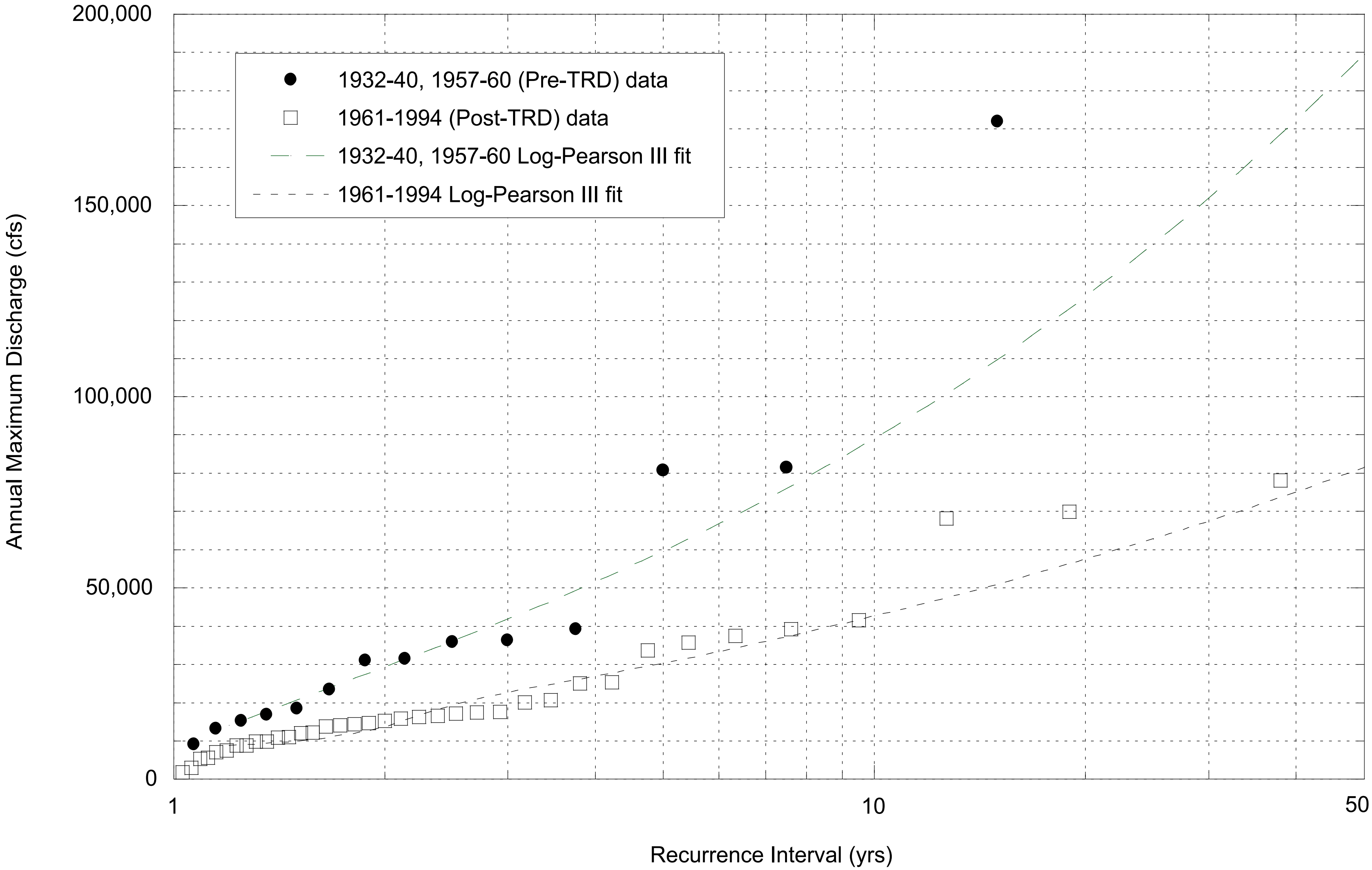


Figure 4.15. Trinity River flood-frequency curves at Burnt Ranch (RM 48.6) before (1912-1960) and after (1961-1995) construction of TRD.

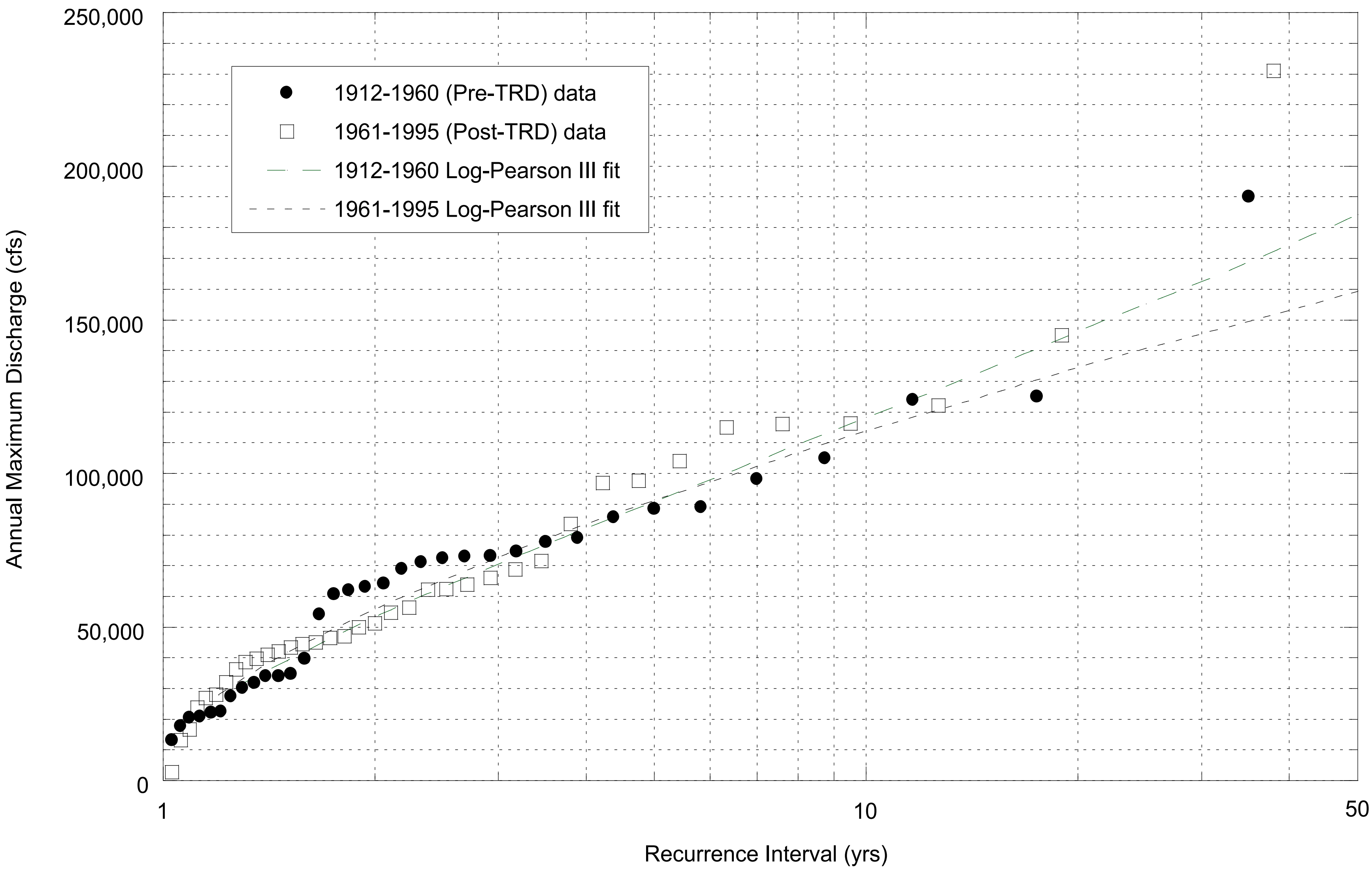


Figure 4.16. Trinity River flood-frequency curves at Hoopa (RM 12.4) before (1912-1960) and after (1961-1995) construction of TRD.

Table 4.5. Comparison of pre- and post-TRD flood magnitudes at USGS Trinity River gaging stations.

	Lewiston (RM 110.9)	Burnt Ranch (RM 48.6)	Hoopa (RM 12.4)
Pre-TRD 1.5-yr flood (cfs)	10,700	21,200	39,000
Post-TRD 1.5-yr flood (cfs)	1,070	10,700	42,000
Percent of pre-TRD	10%	50%	108%
Pre-TRD 10-yr flood (cfs)	36,700	88,400	118,000
Post-TRD 10-yr flood (cfs)	7,500	40,500	114,000
Percent of pre-TRD	20%	46%	97%

Downstream from Lewiston, a reduction in the 10 to 30 percent exceedence probabilities is still present, but the effect is moderated by tributary flows.

A consistent trend emerges from the flow-duration curves at all three locations: (1) the magnitude of higher flows, particularly those exceeded less than 50 percent of the time, decreased as a result of the TRD; and (2) extremely low flows, exceeded more than 85 percent of the time, increased as a result of the TRD (Figures 4.17 to 4.19). The reduced higher flows were due to lake storage of winter baseflows and snowmelt runoff, and to a lesser degree, elimination of winter storm contributions from the upper Basin. The low-flow magnitude increase for the 85 to 100 percent exceedence was due to artificially high summer baseflows, particularly after 1978 when summer flows were increased to 300 cfs. Finally, the flattening of the post-TRD flow-duration curves also indicates a reduction in flow variability, which is best illustrated by comparing the dramatic differences in pre- and post-TRD hydrographs (Appendix F).

4.3.1.3 Changing Influence of Tributary Runoff on Post-TRD Mainstem Hydrology

Present-day mainstem floods increase in magnitude downstream as tributaries cumulatively augment flood flows and baseflows (Table 4.6, McBain and Trush, 1997). Post-TRD mainstem hydrology has two flood populations: (1) frequent tributary floods generated by winter storm events, and (2) infrequent mainstem reservoir releases caused by unusually large snowpack runoff, a major upstream winter flood, or a full reservoir that triggers a dam safety release. These releases occur days or weeks after the actual runoff event(s) and generally are not synchronized with natural tributary flood peaks. As tributary contributions increase downstream, there is a transition near Douglas City where the magnitude and frequency of tributary-induced floods exceed the magnitude and frequency of peak dam releases (see McBain and Trush, 1997 for details). The influence of tributary flows to mainstem Trinity River flows between Lewiston Dam and the North Fork Trinity River was evaluated by Fredericksen, Kamine, and Associates (1980) by examining three exceedence curves for the mainstem Trinity River: below Canyon Creek (RM 79.1), below Indian Creek (RM 95.2), and below Deadwood Creek (RM 110.8) (Figure 4.20). The small difference between the three

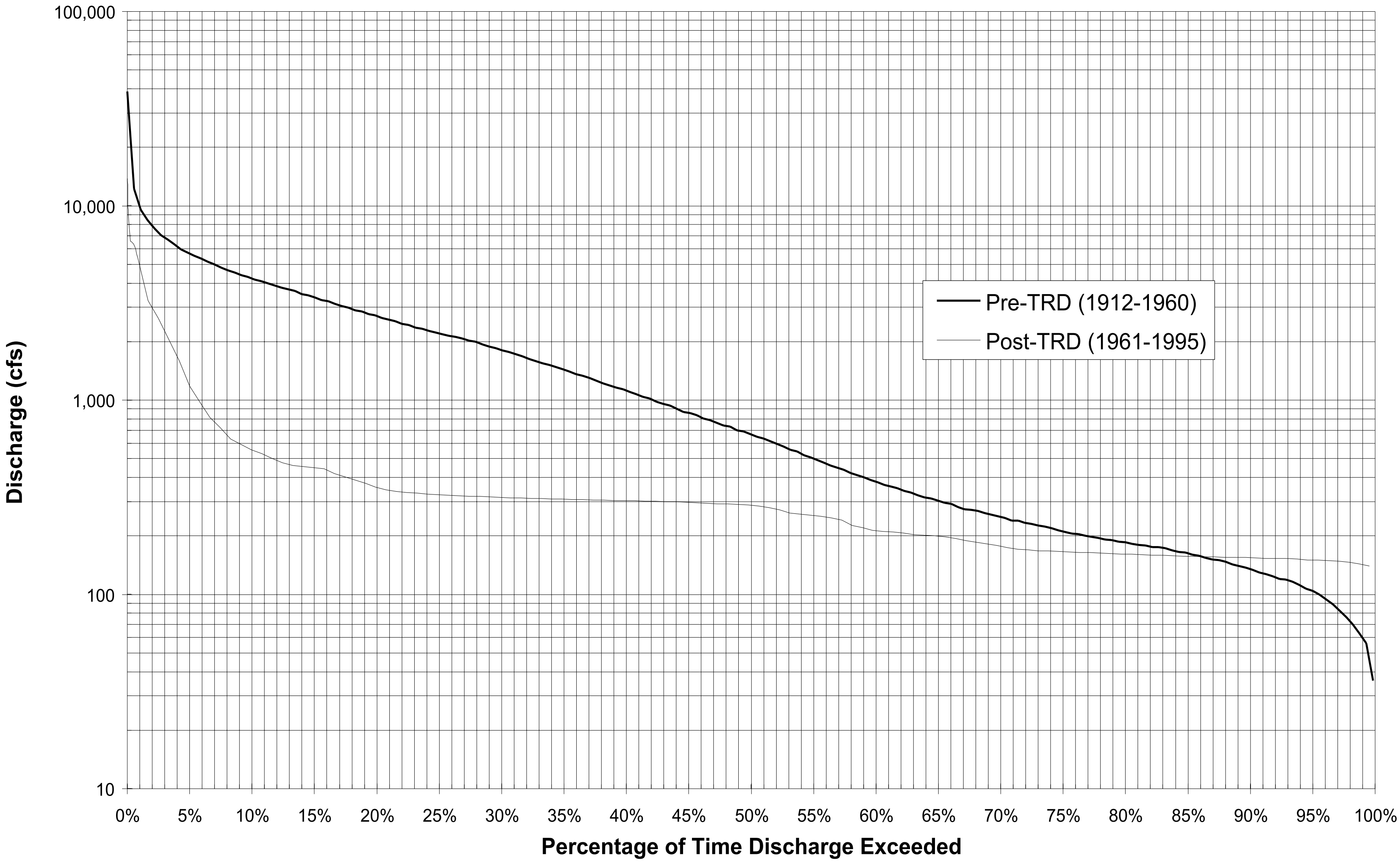


Figure 4.17. Trinity River flow-duration curves at Lewiston (RM 110.9) before (1912-1960) and after (1961-1995) construction of TRD.

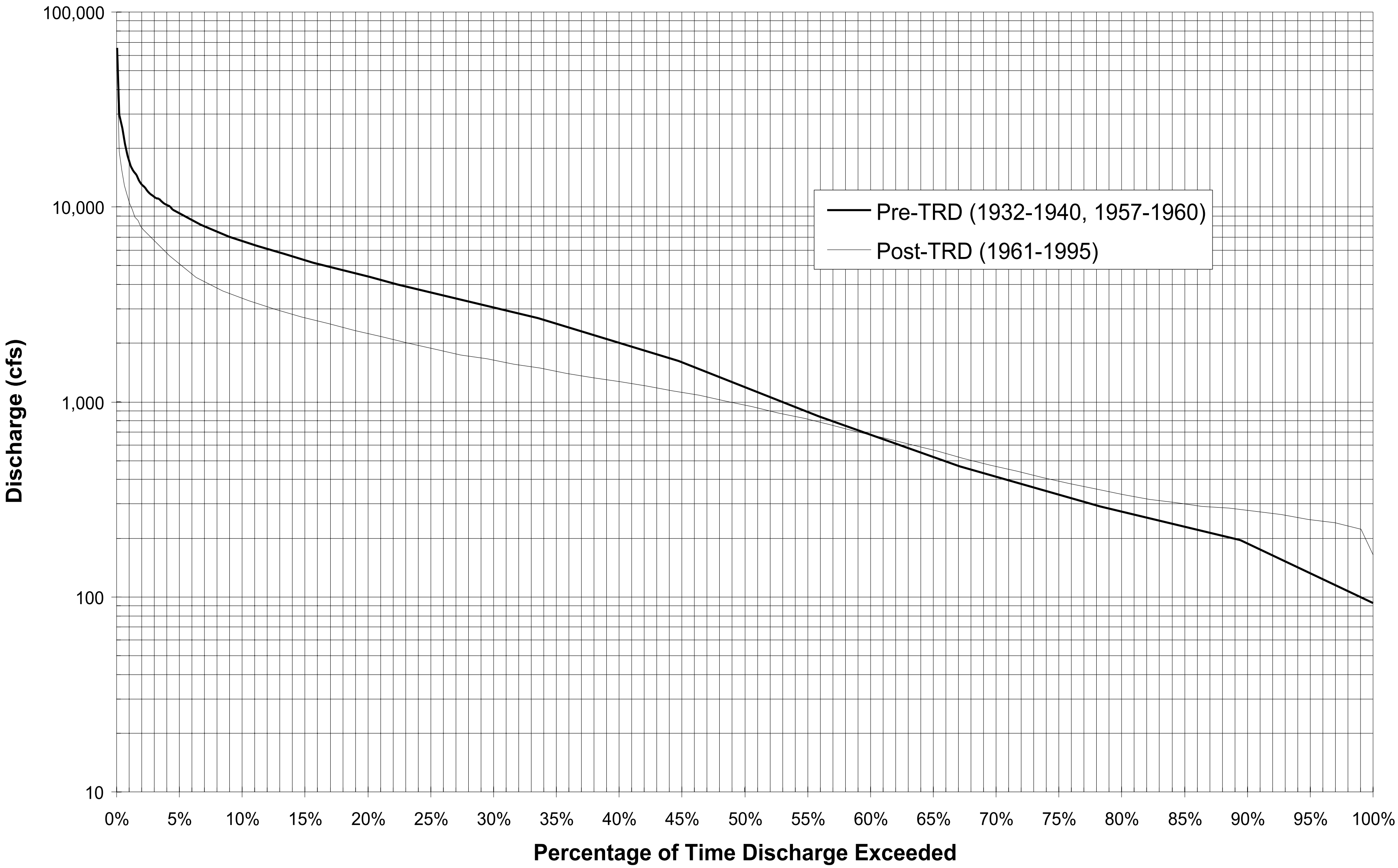


Figure 4.18. Trinity River flow-duration curves at Burnt Ranch (RM 48.6) before (1912-1960) and after (1961-1995) construction of TRD.

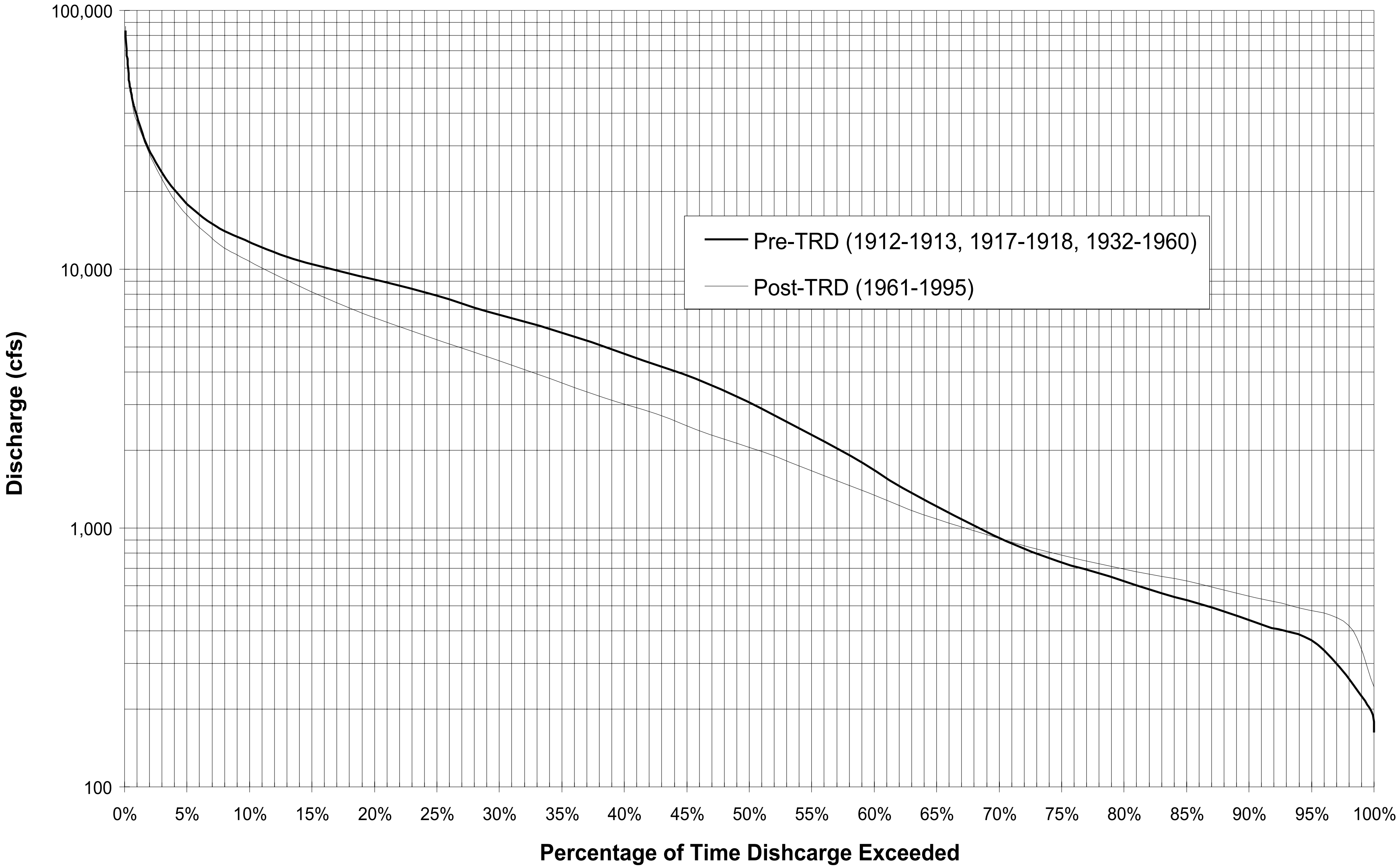


Figure 4.19. Trinity River flow-duration curves at Hoopa (RM 12.4) before (1912-1960) and after (1961-1995) construction of TRD.

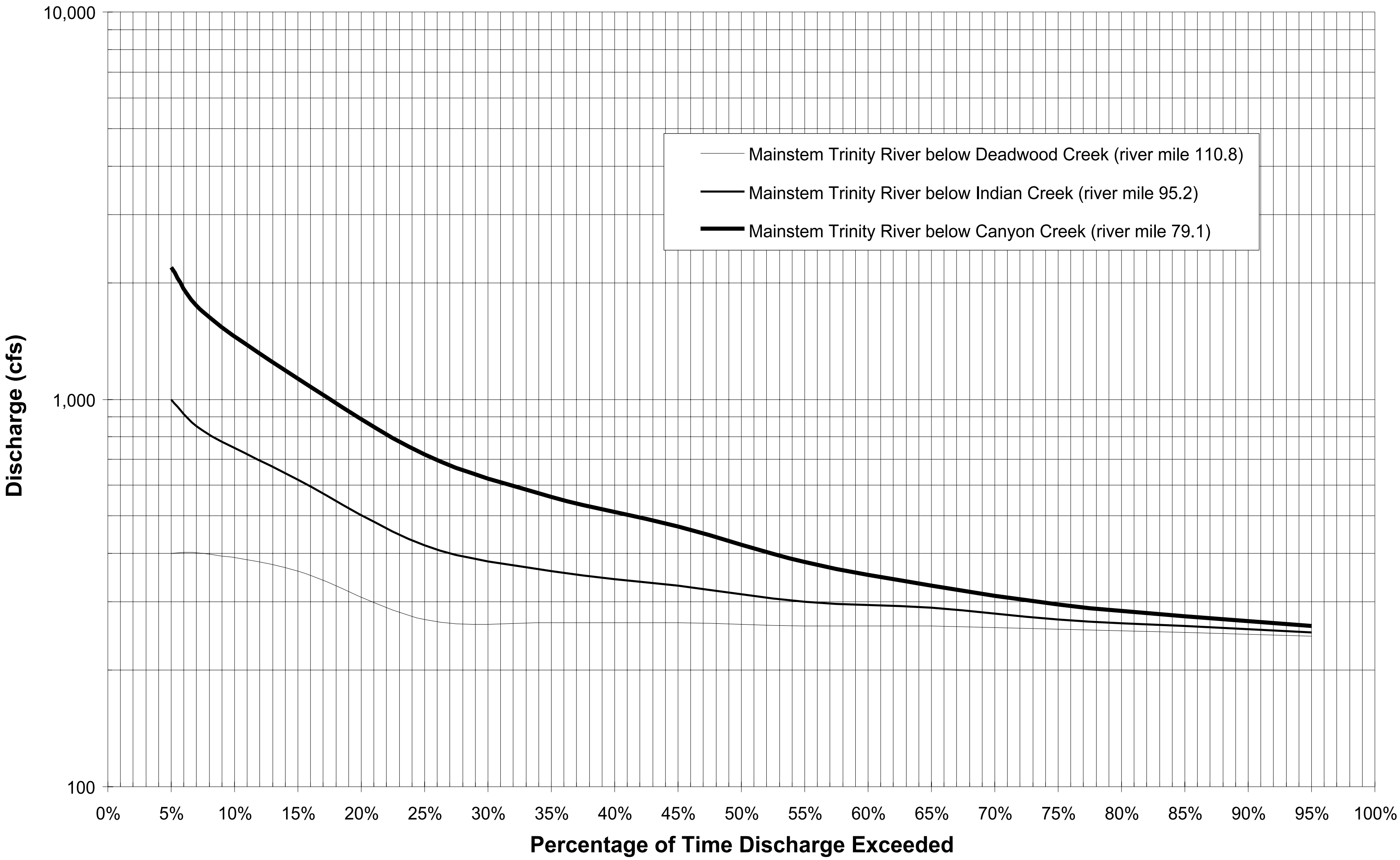


Figure 4.20. Trinity River modeled flow-duration curves at three locations between Lewiston and North Fork Trinity River.

curves for low flows (>65 percent exceedence) was primarily due to the minor summer baseflow contribution of the small tributaries to mainstem Trinity River flows. However, the divergence of the three curves for larger flows was due to the significant tributary contribution during winter storms, winter baseflows, and snowmelt period. Figure 4.20 and Table 4.6 were developed using simple additive models of tributary flows due to the lack of longitudinal streamflow gaging on the mainstem Trinity River. Flows of a given exceedence (recurrence) are usually not additive due to regional runoff differences. However, these analyses, while not precise, illustrate that tributaries contribute a significant volume of flow during winter and spring baseflow periods, as well as during winter storm events. For example, a 300-cfs release can be at least tripled within 30 miles downstream from Lewiston Dam.

> Tributaries downstream of Lewiston increase flood magnitudes down-river, but provide minor contribution to snowmelt runoff or summer baseflows.

4.3.2 Missing Hydrograph Components

Most ecological consequences of the TRD were not as obvious or direct as the lost habitat above Lewiston. The snowmelt hydrograph (including both snowmelt peak and recession hydrograph components) was almost eliminated downstream; today, only a few downstream tributaries contribute significant snowmelt. No mention is made of this in early project evaluations, not even by Moffett and Smith (1950). Big winter floods, often associated with rain-on-snow runoff, also were eliminated, but this was generally considered a benefit to humans and salmon alike. The TRD mostly eliminated all winter storm flows at Lewiston (excluding downstream tributary contribution), with the exception of dam safety releases in wetter years (e.g., in WY1974). Dam safety releases are generally much less (<14,500 cfs) than unregulated inflow into Trinity Lake. Finally, the year-round flow release of 150 to 250 cfs blurred any previous distinction between summer and winter baseflows and eliminated baseflow variability. To illustrate the change in flows since TRD operations began, each unregulated annual hydrograph (the unregulated daily average flow entering Trinity Lake) has been overlaid onto its regulated annual hydrograph (the USGS gaging station at Lewiston) in Appendix F. Refer to McBain and Trush (1997) and Section 5.4 for greater detail on pre-TRD and post-TRD hydrograph components. Given the importance of the annual hydrograph components in transporting sediment, creating and maintaining alternate bar sequences, and influencing riparian life-history, their loss signaled the eventual habitat loss and ecosystem impairment that was to follow.

4.3.3 Riparian Vegetation

4.3.3.1 <u>Riparian Encroachment and Bar Fossilization</u>

Riparian vegetation downstream from Lewiston Dam encountered more than 30 years of man-made droughts since the TRD began diverting up to 92 percent of the annual inflow. With only 150 cfs to 250 cfs released year-round through the 1970's (except occasional, higher dam safety releases), seedlings and saplings escaped desiccation and (or) scour. These significantly reduced, and virtually constant instream flows impacted channel morphology and the river ecosystem by allowing woody riparian vegetation to rapidly encroach across the former active channel and down to the edge of the low-water channel (Figure 4.21 and 4.22).

At Gold Bar (RM 106.3) willow and white alder rapidly encroached by 1975 (Figures 4.23 to 4.26). The downstream end of the median bar shows mature trees approximately 50 feet tall and over a foot in diameter toppled by the 1974 flood (peaking at 14,500 cfs),

Table 4.6. Summary of pre- and post-dam flood frequency estimates as a function of distance downstream from Lewiston Dam, demonstrating the influence of tributary floods on mainstem flood flows.

	1.2 Year Flood			1.5 Year Flood			2.33 Year Flood			5 Year Flood		
River Mile	Pre-dam	Post-dam	Percent of Pre-dam	Pre-dam	Post-dam	Percent of Pre-dam	Pre-dam	Post-dam	Percent of Pre-dam	Pre-dam	Post-dam	Percent of Pre-dam
112	7,171	630 *	9% *	11,813	1,110 *	9% *	14,599	2,160 *	15% *	26,745	4,500 *	17% **
112	7,171	400 **	6% **	11,813	400 **	3% **	14,599	400 **	3% **	26,745	400 **	1% **
107.5	7,478	681 **	9% **	12,376	816 **	7% **	15,315	1,189 **	8% **	28,393	1,826 **	6% **
104	7,616	807 **	11% **	12,752	1,060 **	8% **	15,834	1,760 **	11% **	29,987	3,204 **	11% **
95.4	8,338	1,469 **	18% **	13,951	1,981 **	14% **	17,319	3,398 **	20% **	33,209	5,991 **	18% **
93.8	9,260	2,314 **	25% **	15,309	3,076 **	20% **	18,939	5,182 **	27% **	36,397	8,749 **	24% **
92.8	9,918	2,917 **	29% **	16,402	3,914 **	24% **	20,292	6,673 **	33% **	39,336	11,291 **	29% **
87.8	10,652	3,590 **	34% **	17,520	4,803 **	27% **	21,641	8,159 **	38% **	42,121	13,700 **	33% **
79.2	11,569	4,430 **	38% **	19,073	5,986 **	31% **	23,575	10,290 **	44% **	46,348	17,356 **	37% **
72.5	14,120	6,769 **	48% **	23,648	9,397 **	40% **	29,365	16,670 **	57% **	59,573	28,795 **	48% **

	10 Year Flood			25 Year Flood			50 Year Flood		
River Mile	Pre-dam	Post-dam	Percent of Pre-dam	Pre-dam	Post-dam	Percent of Pre-dam	Pre-dam	Post-dam	Percent of Pre-dam
112	36,700	7,600 *	21% *	51,431	13,400 *	26% *	63,958	17,300 *	27% *
112	36,700	400 **	1% **	51,431	400 **	1% **	63,958	400 **	1% **
107.5	39,392	2,538 **	6% **	55,624	3,385 **	6% **	69,985	4,365 **	6% **
104	42,501	5,008 **	12% **	62,328	8,156 **	13% **	80,882	11,533 **	14% **
95.4	47,602	9,059 **	19% **	70,352	13,867 **	20% **	92,227	18,997 **	21% **
93.8	52,220	12,727 **	24% **	77,580	19,012 **	25% **	101,768	25,273 **	25% **
92.8	56,870	16,421 **	29% **	84,941	24,251 **	29% **	112,160	32,110 **	29% **
87.8	61,067	19,755 **	32% **	91,842	29,163 **	32% **	121,599	38,319 **	32% **
79.2	67,798	25,101 **	37% **	102,908	37,039 **	36% **	137,538	48,805 **	35% **
72.5	88,949	41,901 **	47% **	139,728	63,246 **	45% **	189,598	83,053 **	44% **

Note: Tributary floods and high flow releases from the dam do not usually have similar timing, thus the distribution of dam releases are considered different and non-additive to tributary floods. Therfore, it is assumed that dam releases during tributary floods were 400 cfs.

Boxed values illustrate where tributary derived flood frequency regime exceeds dam release flood frequency regime.
* flood frequency estimates are from actual post-dam releases.
** flood frequency estimates assume a 400 cfs release from dam (tributary floods not timed with dam releases, thus not additive).

Figure 4.21. Typical fossilization of a point bar surface (circa 1995) near Douglas City (RM 91.8) by encroachment of riparian vegetation that has occurred since TRD construction.

although most trees on the bar appear unaffected (Figure 4.25). Upstream, approximately 200 feet from the riffle crest, other mature trees along the right bank also were toppled as the flood spilled onto the floodway and then returned across the newly formed riparian berm. Large woody debris on the right bank in the pre-TRD photograph (faintly visible as scattered lines in Figure 4.23) is conspicuously absent in later photographs.

As these established plants grew, elevated hydraulic roughness generated by the stems and dense understory along the low water channel encouraged fine sediment deposition during tributary-derived high flows, providing seedbeds for additional plants. Their foothold on previously dynamic alluvial bars soon became permanent, such that by 1970 Lewiston releases were incapable of scouring the bars or the trees. A WY1997 flow of approximately 12,000 cfs at Gold Bar, similar to that of the WY1974 flood, dislodged only a few trees (Figure 4.25). The extensive root system of riparian vegetation along the length of the mainstem low-water channel immobilized, or "fossilized," the bars' alluvium (Figure 4.21). In this fossilized state, alluvium can no longer be transported downstream, thus eliminating another gravel/cobble source for sustaining an alternate bar morphology.

The continual low flow releases from the TRD allowed riparian vegetation to initiate, establish, and mature along the low flow channel, eventually fossilizing the channel and inducing sand deposition to form a confining berm.

Riparian encroachment was fastest upstream from Weaver Creek. Ritter (1968) had already observed extensive willow colonization along the low-water channel (150 to 200 cfs water surface) by 1965, and significant deposition of fine sediment

Figure 4.22. Development of riparian berm on the mainstem Trinity River at the confluence with the North Fork Trinity River (RM 72.4) looking upstream. The top photograph was taken pre-1960, the bottom photograph was taken in 1996.

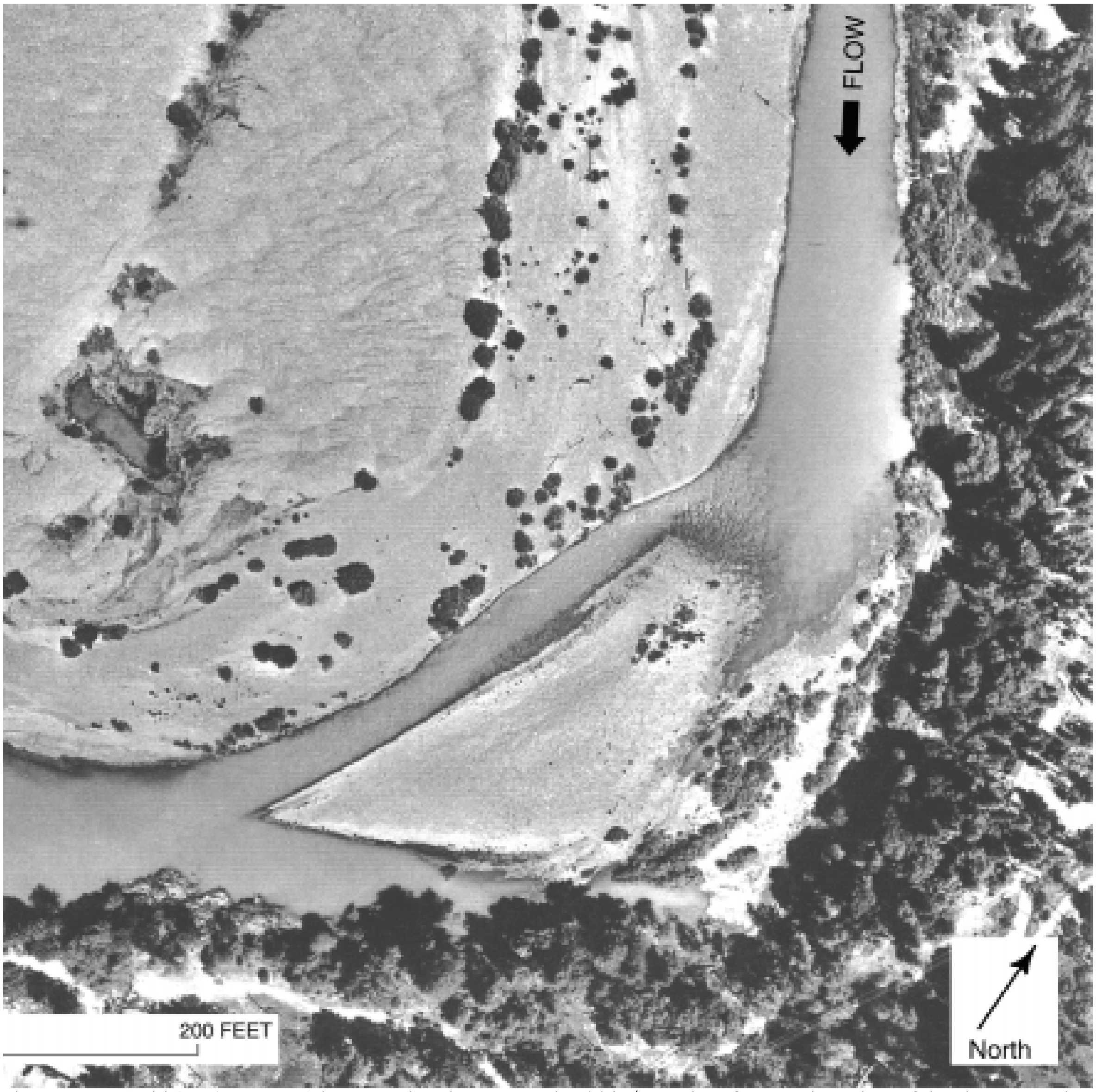


Figure 4.23. Gold Bar (RM 106.3) in 1961, showing exposed cobble/gravel surfaces and patches of riparian vegetation typical of pre-project conditions. Note woody debris on right bank (looking downstream) floodplain.

within this emerging riparian band. This sediment deposition occurred primarily during the December 1964 flood; deposition ranged from almost none near the dam to more than 3 feet near the Weaver Creek confluence. Ritter (1968) also observed at Rush Creek, a few years following dam closure:

The downstream cross-section, which had no earthmoving activity, showed a small amount of aggradation, but the most evident change was the great profusion of young willows which grew along the right bank since the first survey [in 1960].

Four years of optimal growing conditions easily produced conspicuous 6-foot-high willows, suggesting that seedling survival in WY1964 and WY1965 was abnormally high.

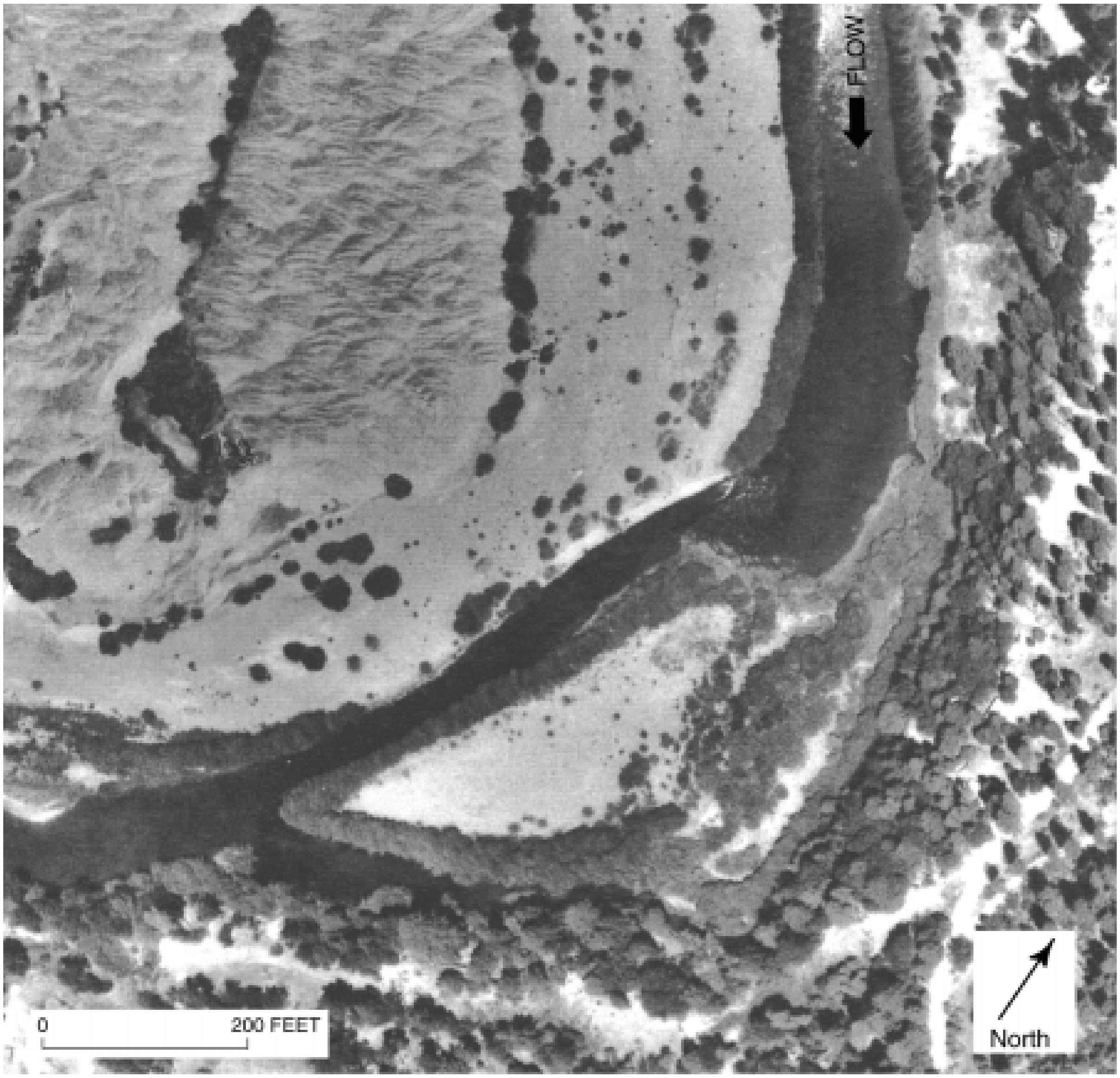


Figure 4.24. Gold Bar (RM 106.3) in 1970, showing effects of seven years of riparian encroachment on alluvial deposits. Note thick riparian band developing along low-water surface.

Pelzman (1973) concludes that riparian encroachment was prevented prior to the TRD primarily by rapid flow reduction during the summer when seedlings were initiating. He states that receding flows and associated declines in groundwater tables caused many seedlings to desiccate. The construction and operation of the dams eliminated this mortality agent and greatly increased seedling survival. Pelzman (1973) also notes, "Reduced spring flows, followed by stabilized flow, exposed considerable areas of the stream channel with moist soil during the period most favorable for germination." Seedling survival close to the Lewiston Dam was almost guaranteed. Even with downstream tributary flow augmentation and occasional floods capable of mobilizing the mainstem's channelbed surface (especially below Dutch Creek at RM 86.3), rapid plant establishment reached the North Fork Trinity River confluence.

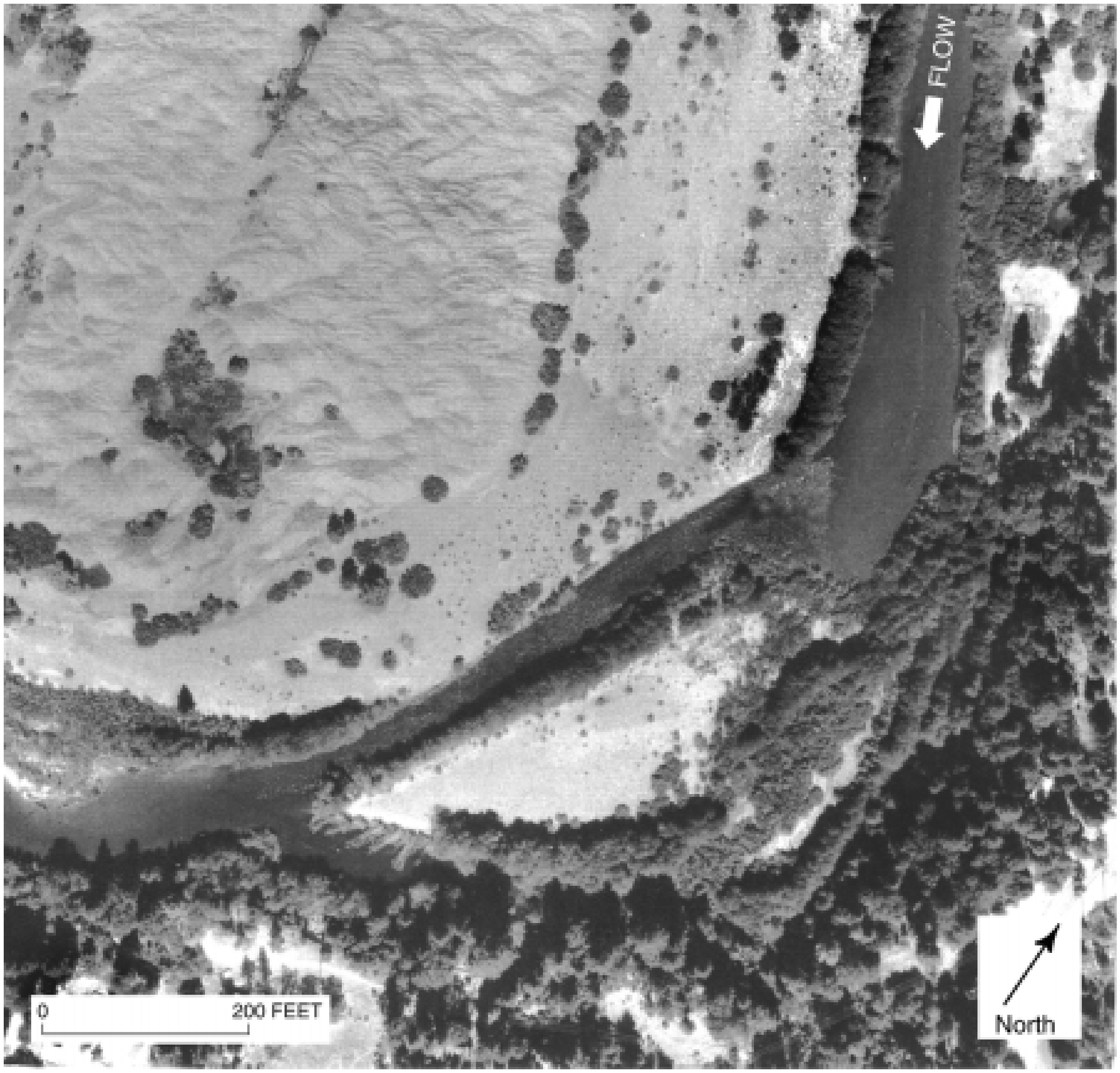


Figure 4.25. Gold Bar (RM 106.3) in 1975, showing twelve years of riparian encroachment. Note minimal effect of January 1974 14,000 cfs flood on riparian berm.

Later, Evans (1980) documented the total change in the areal extent of riparian vegetation between 1960 and 1977. He reported that riparian stands of willow and alder increased from 187 acres to 853 acres between Lewiston and the North Fork Trinity River. Early on, these communities were dominated by willow overstories. As these communities matured, alders replaced willows in the overstory. He also predicted that broad-leaf riparian plants on the riparian berm would be shaded out and ultimately replaced by upland conifer species in approximately 35 years. Wilson (1993) repeated Evan's (1980) areal census, extending the temporal analysis to include 1989 riparian conditions. Wilson's results were comparable, finding 313 acres in 1960 and 881 acres in 1989 for the same length of mainstem. Impact to the mainstem riparian community was more serious than a shift in riparian acreage accounting. Community structure was simplified by a reduction in diversity, with an understory

Figure 4.26. Gold Bar (RM 106.3) in 1997, showing the current status of morphology downstream to North Fork Trinity River. Note that willow patches on old right bank (looking downstream) floodplain are same trees as shown in 1961 photo.

now dominated by dense blackberry. Cottonwood forests, which require overbank deposits and channel migration for initiation and establishment, have disappeared.

4.3.3.2 Riparian Berm Formation

Deposition of fine sediment within newly encroached riparian plant stands created levee-like features along the low-water's edge, referred to as "riparian berms" (compare

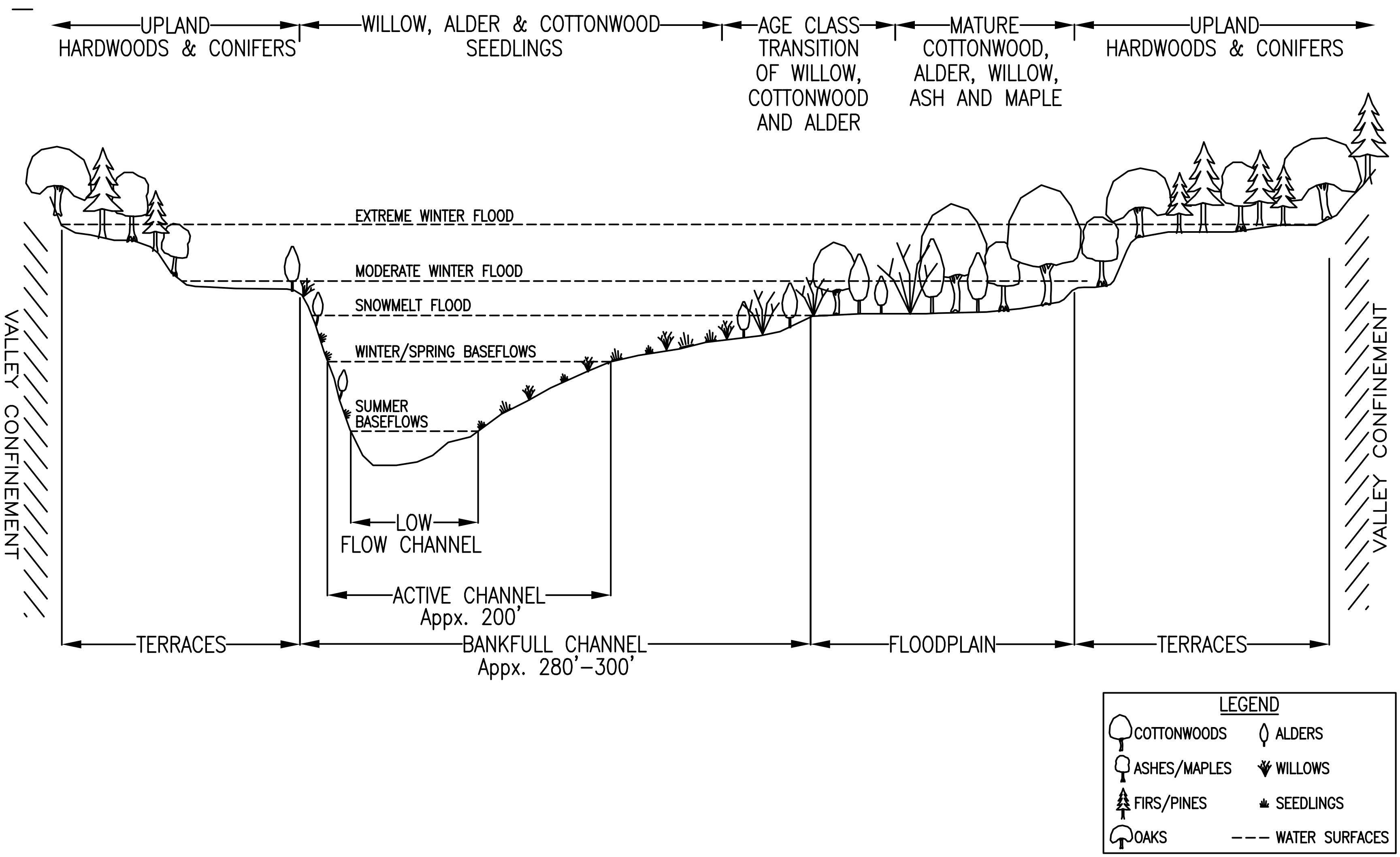


Figure 4.27. Present idealized channel cross section and woody riparian communities near Steiner Flat (RM 91.7).

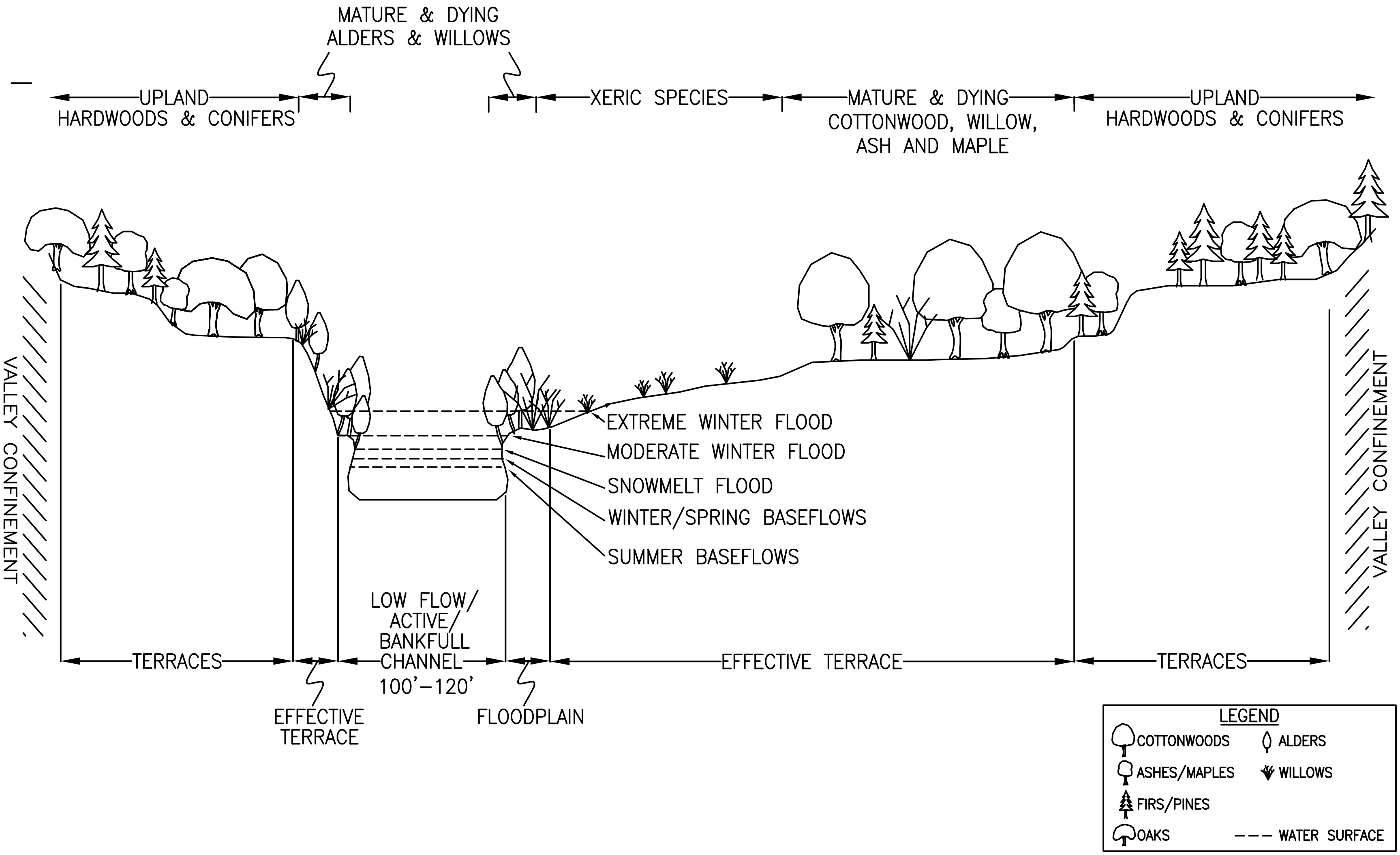


Figure 4.28. Conceptual evolution of the Trinity River channel cross section following the operation of the TRD.

Figure 4.27 and 4.28). They are now ubiquitous depositional features throughout the mainstem, signaling a change in alluvial behavior riverwide. Riparian berms formed within the historical active channel margin. Low flows released in the late 1960's and early 1970's were well below the flows required to inundate the pre-TRD active channel margin. Willow growth flourished near this low flow waterline, then colonized upslope to the first sharp slope break (Figure 4.28). This break was at the active channel margin, corresponding to the elevation of pre-TRD high winter baseflows. The varying width of the present-day riparian encroachment band probably reflects, in most locations, pre-TRD active channel dimensions. The progression of riparian colonization onto the Gold Bar median bar (Figures 4.23 to 4.26) illustrates this widening of the riparian zone at the riffle crest where the pre-TRD active channel gently sloped up the median bar. Along the steep flank of this active channel, upstream from the riffle crest, riparian encroachment has been restricted to a relatively narrow band.

> The riparian berm fossilized alluvial deposits, simplified the channel, reduced habitat diversity, removed floodplain access, and reduced riparian species and age class diversity.

During riparian berm removal at the Sheridan (RM 82.0) and Steiner Flat (RM 91.8) bank rehabilitation sites by bulldozers, mature willow trunks that appeared rooted on the riparian berm tops were actually buried in the riparian berm and rooted on the original pre-TRD channelbed surface (McBain and Trush, 1997). A sharp interface between the original cobblebed surface and recently aggraded coarse sand of the riparian berm revealed the abrupt depositional environment created by maturing saplings along the channel edge. Mature willows had several sets of adventitious roots along their buried trunks, each set presumably correlated to a discrete depositional event. The lack of large gravels and cobbles in the riparian berms' stratigraphy also indicated the pronounced role of small to intermediate floods in facilitating riparian berm formation. Only one coarse layer was excavated, presumably corresponding to the WY1974 flood. White alders approximately 20 years old were rooted on this layer. Although cobbles were deposited onto the riparian berms during this event, the willows had become sufficiently established to resist removal.

Today, riparian berms exceeding 7 feet in height are extensive below Junction City (RM 80.0). Some riparian berms are still aggrading but at highly variable rates. The 20-year-old alders in the Sheridan bank-rehabilitation site (RM 82.0) were buried by only 0.8 foot of fine sediment though they were rooted 5 feet high on the riparian berm. In contrast to this slow accretion (at least since the mid-1970's), recent blackberry understories along the left bank of the Gravel Plant monitoring site (RM 105.5) trapped several feet of coarse sand in one 6,000 cfs dam release in WY1992 (Trinity Restoration Associates, 1993). Riparian berms can continue aggrading if higher flood elevations are experienced, if the riparian berm vegetation becomes even denser, or if fine sediment supply increases.

4.3.4 Changing Channel Morphology

TRD releases created a Trinity River that abandoned its former floodplain and therefore narrowed the river corridor. Channel width also narrowed. For example, the cross-section at the Lewiston USGS cableway narrowed (from 187 to 137 feet) and became shallower (from 3.9 to 2.5 feet), but it almost doubled in mean velocity (from 1.2 to 2.5 feet/sec) at a discharge of approximately 840 cfs (Figure 4.8). Cross sectional-shape changed quickly, with alluvial channel reaches affected most. Asymmetrical cross sections, typical of alluvial channels with alternate bars, were transformed into uniform trapezoidal configurations (Figures 4.27 to 4.28).

The present mainstem channel location is almost a snapshot of its location in 1960; meanders have been immobilized by flow regulation and subsequent encroachment of riparian berms. Some immobilized reaches, however, developed subtle meander patterns between the riparian berms such that their thalwegs were only slightly deeper (0.5 foot) than the mean channel depth. One or more present-day meanders can be placed into half a meander of the pre-TRD channel (Figure 4.29). Today, the presence of a more defined meandering thalweg in an erodible channel, especially downstream from the Dutch Creek confluence (RM 86.3), indicates a trend back to a dynamic alternate bar morphology although with a shorter wavelength and amplitude than pre-TRD conditions.

4.3.5 Lost Alluvial Features, Lost Habitat Complexity

Flow regulation triggered a chain of geomorphic and riparian events that by the mid-1970's had rapidly simplified habitat complexity in the mainstem. One salient reason for habitat degradation was the loss of alternate bars and their associated sequences of pool-riffle-runs (Figure 4.30). From Lewiston Dam to Indian Creek, fossilized alternate bars and point bars dominate the channel morphology (McBain and Trush, 1997). Accretion of flow and sediment from tributaries has allowed some bar formation, particularly downstream from the Indian Creek confluence (RM 95.2). However, these bars do not have the size, shape, mobility, or riparian vegetation expected of unregulated alternate bars. Recovery of an alternating bar morphology is never fully realized until downstream from the confluence with the North Fork Trinity River (RM 72.4).

Lost alluvial features compromised salmonid habitat by producing monotypic habitat characterized by extensive runs with high velocities (Figure 4.30). Habitat diversity is critical, not only because species utilize different habitats, but because individual fish use different habitats during their daily activities (e.g., feeding, holding, evading predators). Monotypic environments meet all needs of very few species and generally lack adequate microenvironments for the specific activities of most species (i.e., feeding or providing cover, etc.). Such inadequacies force fish into sub-optimal habitat.

Another consequence of lost alternate bar morphology was the transformation of asymmetrical channel cross sections into uniform, trapezoidal cross sections. Today's salmonid rearing habitat, especially fry habitat, is constrained to narrow ranges of slower flows located immediately adjacent to the channel banks (Figure 4.30) (Section 5.2). Low-velocity areas are used by salmonid fry, as well as fry of suckers and dace, and lamprey ammocoetes. The shallow slackwater habitat preferred by recently emerged fry nearly disappears in the present channel at intermediate discharges (between 400 cfs and 2,000 cfs), only to reappear at flows greater than 2,000 cfs once riparian berms have been overtopped (USFWS, 1997). Flows greater than 1,500 cfs begin to inundate the area behind riparian berms and create slow-water areas suitable to salmonid fry. As flows decrease, some fry do not return to the mainstem and become stranded in isolated pools formed behind riparian berms.

> Loss of flow volume, flood magnitudes, and flow variability virtually eliminated the fluvial processes responsible for creating and maintaining high quality salmonid habitats. Subsequent riparian encroachment, fine sediment accumulation in the mainstem, and loss of coarse sediment supply and transport contributed to decreased salmonid habitat quantity and quality in the mainstem Trinity River.

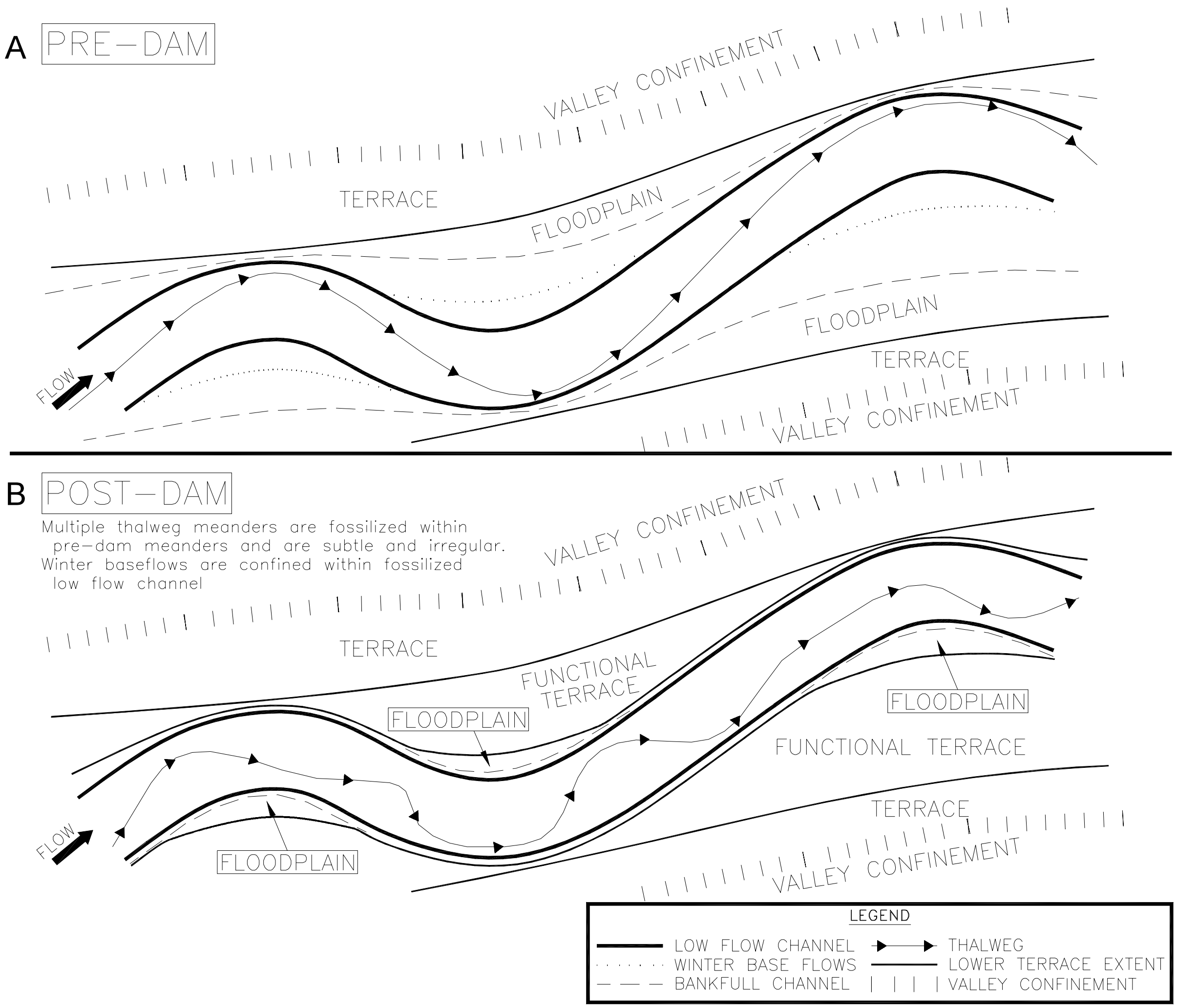


Figure 4.29. Conceptual evolution of the Trinity River planform geometry from Lewiston Dam to the North Fork Trinity River due to TRD operation. A) Pre-TRD meanders were fossilized by riparian vegetation, and remain so under post-TRD conditions. B) A few locations do exhibit some slight meandering of the thalweg within the fossilized banks.

4.3.6 Colder Summertime Water Temperatures

Prior to construction of the TRD, mean monthly water temperatures of the Trinity River at Lewiston were quite variable. During the winter months, temperatures were 39 to 41°F and were generally lowest during January. With the onset of spring and increasing day length, mean monthly water temperatures slowly increased to about 53.6°F in May and continuously increased until July and August when water temperatures were highest, usually exceeding 68°F. During these summer months, a difference as great as 12°F was recorded between daily maximum and minimum water temperatures, and maximum daily water temperatures exceeded 80°F on several occasions (Moffet and Smith, 1950). Because of low-flow conditions (100 cfs) during these warm periods,

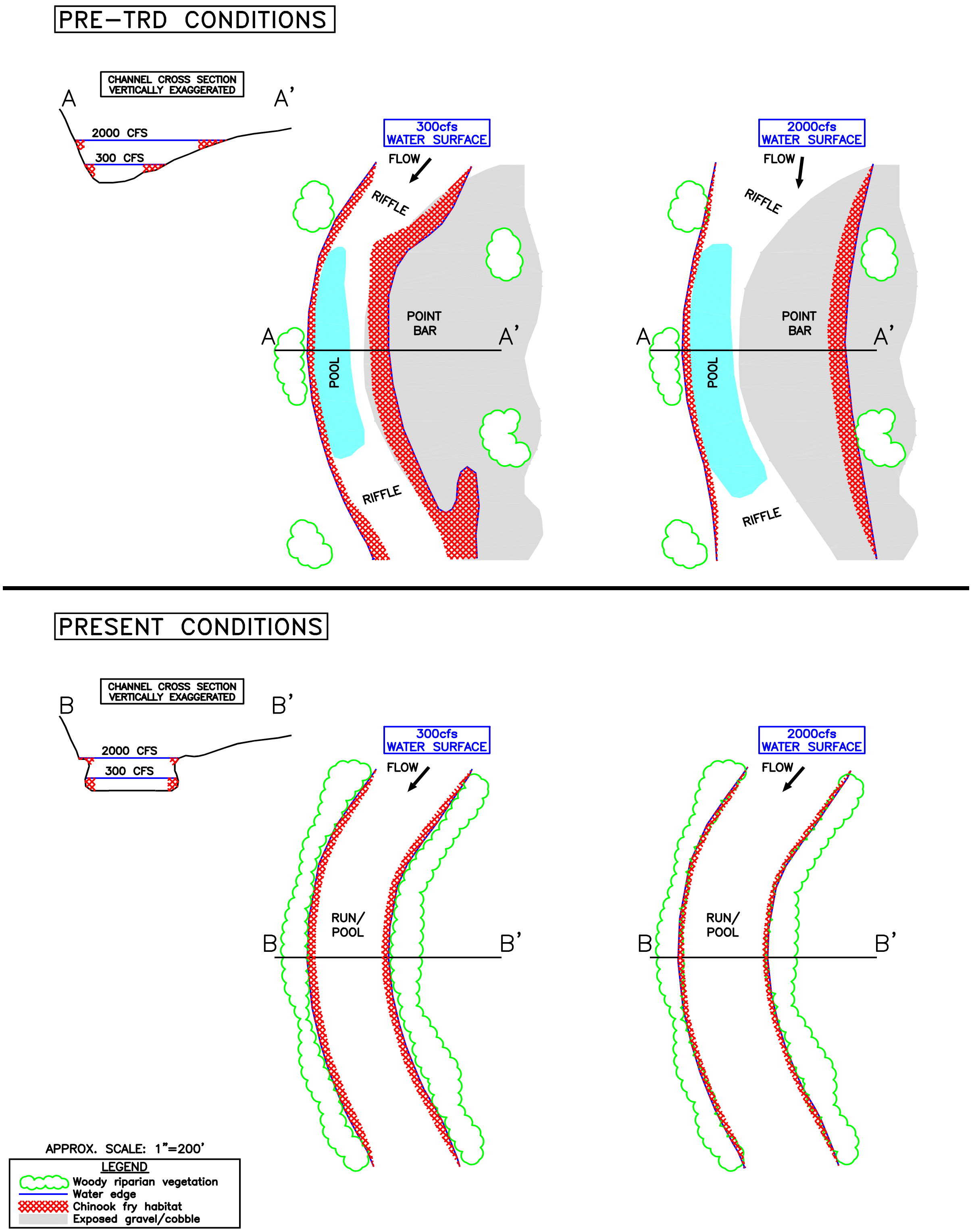


Figure 4.30. Idealized pre-TRD point bar showing relative surface area of fry chinook rearing habitat in comparison with present conditions of riparian encroachment and narrow channel.

pools stratified and surface water was as much as 7°F warmer than the bottom (Moffet and Smith, 1950). From September to December water temperatures continued to decrease as a result of cooler meteorological conditions and reduced day length.

Since construction of the TRD, water temperatures at Lewiston have become relatively stable and conditions are therefore much different from pre-dam conditions (Figure 4.31). From November to May, water temperatures have become as much as 4°F warmer, and conditions for the remaining months of the year have become as much as 20°F colder. It was generally believed that the TRD would increase salmonid production due to more stable flows and cooler summer water temperatures provided by dam releases. This increased production was never realized. Most salmonid smolts outmigrated before summer water temperatures were unsuitable. Rearing juvenile salmonids (pre-TRD) remained in the cooler habitats above Lewiston that were predominantly fed by snowmelt, or sought the cool refugia in stratified pools. Operation and construction of the TRD blocked these habitats and altered flows such that pools no longer stratify.

Although meteorological conditions can influence the temperature of water released from Lewiston Dam, the operation of diversions through the Clear Creek Tunnel to the Sacramento River can have a greater effect. In the summer, when diversions to Whiskeytown Reservoir are large (as great as 3,200 cfs), Lewiston Reservoir essentially becomes a slow-moving river and remains cold (Trinity County, 1992). Conversely, when diversions are low and residency time is high, Lewiston Reservoir temperatures begin to warm during the summer months.

> The TRD changed pre-TRD water temperature patterns downstream of Lewiston: winter water temperatures are warmer than pre-TRD temperatures, and summer temperatures are colder.

During the summer, two types of operational scenarios have been used to reduce this residency time (Trinity County, 1992). During periods of low diversion and warm meteorologic conditions, "slugging" of Lewiston Reservoir is usually requested by the Trinity River Fish Hatchery to obtain cold water temperatures; "Slugging" is a short-term, high-volume diversion through the Clear Creek Tunnel followed by refilling of Lewiston Reservoir with cold Trinity Lake water. The other scenario is to divert large volumes of water at a continuous rate through Lewiston Reservoir by way of the Clear Creek Tunnel or down the Trinity River. The latter method is rarely used.

Reservoir storage also affects water temperatures in the Trinity River. Although uncommon, the storage in Trinity Lake can be relatively low, especially as a result of successive dry years. In August 1977, a warm water release (approximately 79°F) made below the TRD resulted in adult and juvenile mortalities in TRFH and in the river downstream. The release occurred when warmer surface waters were drawn through the main power outlet (2,100 feet) in Trinity Dam. The reservoir elevation at the time of the release was 2,145 feet. Cold water releases were resumed downstream when Reclamation operators bypassed the main outlet works and opened the auxiliary outlet (1,995.5 feet).

4.4 <u>Managing the Mainstem for Salmon</u>

Salmon have been the focus of flow management since TRD operations began. When salmon populations began to decline, all management prescriptions, including all flow-release recommendations, dredging operations, and hillslope protection measures, were intended to improve some aspect of salmon populations.

4.4.1 Dam Releases

Preliminary studies determined that TRD releases necessary to maintain the fishery resources of the Trinity River ranged from 150 to 250 cfs (Moffett and Smith,

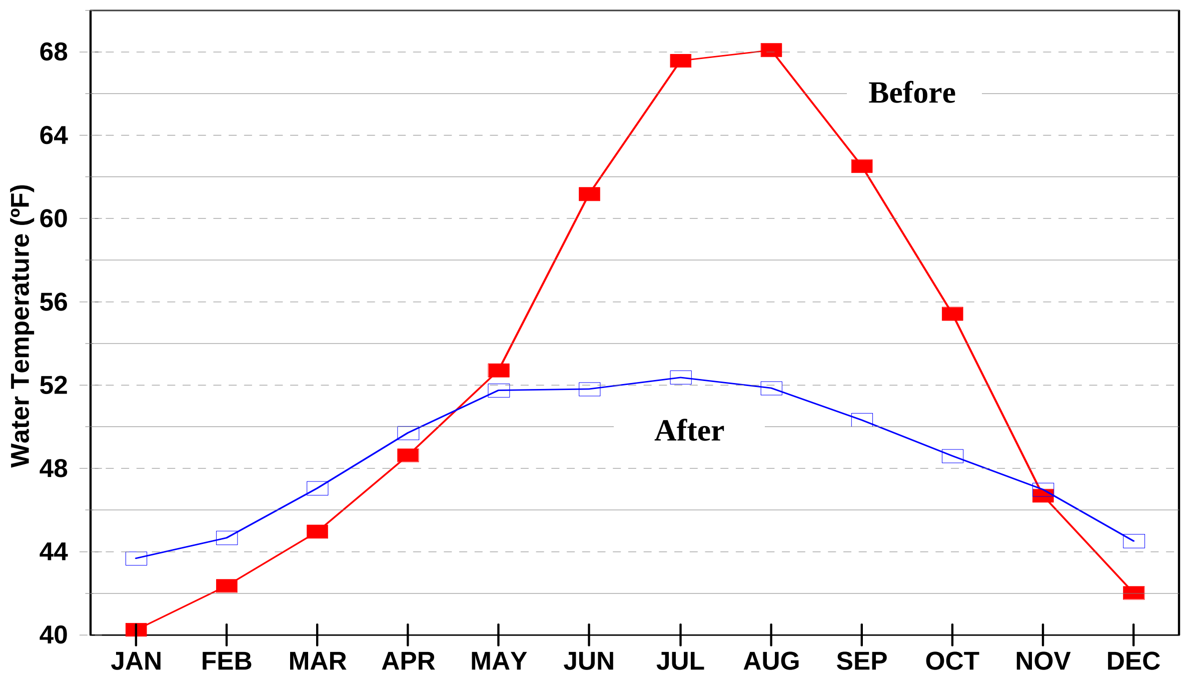


Figure 4.31. Mean monthly water temperatures of the Trinity River at Lewiston before and after construction of the TRD in 1963. Data years were 1942 to 1946, 1959 to 1961, 1964 to 1983, 1987 to 1992.

1950). These recommendations were primarily based on the depth and velocity requirements of spawning chinook salmon. However, after completion of the TRD, subsequent declines in anadromous fish populations were apparent (Hubbel, 1973). To reverse these declines, CDFG initiated a study in 1973, requesting increased releases ranging from 300 to 1,750 cfs during the spring to mimic natural snowmelt conditions. However, drought in 1976/1977 interrupted these experimental flows. In response to public concerns about the status of the fishery resources and to instream flow study needs, Reclamation voluntarily maintained minimum releases of 300 cfs year-round from 1978 through the early 1980's (USFWS, 1983).

During those years, an instream flow study conducted by the Service (USFWS, 1980a) found that increased flows were essential to restore and maintain the Trinity River fishery resources. This study provided the basis for the instream flow volumes put forth in the 1981 Secretarial Decision. Increased annual volumes allowed daily releases to increase to a minimum of 300 cfs in normal or wetter years. Daily releases for dry-year flow regimes (140 TAF) remained between 150 and 300 cfs. Unfortunately, 5 of the first 6 years of the TRFE were dry years, and releases remained low. The series of low releases contributed to the continued decline of the fishery resources, but also jeopardized the TRFE. In response, the Hoopa Valley Tribe filed a successful administrative appeal, which increased the annual flow regime in all years to 340 TAF beginning in 1992. This annual volume allowed for minimum flows of 300 cfs year-round plus additional water that has been used to provide appropriate temperatures for holding spring chinook during the summer that previously held in the cooler waters above Lewiston, as well as releases of higher flows for several studies.

4.4.2 The Trinity River Restoration Program

As described in Chapter 2, Congress established the Trinity River Fish and Wildlife Restoration Program (the Program) in 1984 to reverse salmonid habitat decline below Lewiston. Program objectives were to: (1) increase the quantity and quality of salmonid juvenile and adult habitat in the mainstem; (2) reduce fine sediment contributions to the mainstem from tributaries; and (3) remove fine sediment from critical spawning habitat within the mainstem channel. Over the initial 10-year authorization, the Program mostly focused on controlling fine sediment entering the mainstem from tributary basins.

4.4.2.1 Buckhorn Debris Dam and Hamilton Sediment Ponds

The Program's accomplishments included the construction of Buckhorn Debris Dam and Hamilton sediment catchment ponds, the purchase of the Grass Valley Creek Basin, and the implementation of numerous basin restoration projects (TCRCD/ NRCS, 1998). Construction of Buckhorn Debris Dam and the operation of the Hamilton sediment ponds have prevented a considerable amount of fine sediment from entering the mainstem via Grass Valley Creek. Other mechanical efforts to remove sediment and improve habitat conditions in the river have included cleansing of spawning riffles, dredging of sand from mainstem pools, side channel construction, and a pilot bank rehabilitation program to improve mainstem channel morphology.

Grass Valley Creek is a major source of granitic sand entering the upper river (BLM, 1995). Accumulation of this fine sediment in the mainstem has contributed substantially to the degradation of the river ecosystem and salmonid habitat. VTN Environmental Sciences (1979) and Fredericksen, Kamine, and Associates (1980) recommended periodic dredging of the Hamilton sediment ponds built at the mouth of Grass Valley Creek (Figure 4.1). In the ponds, coarse granitic sand and coarser bedload is settled out before it can enter the mainstem. Since their construction in 1984, the Hamilton sediment ponds, which have a storage capacity of 42,000 yd^3, have been dredged as needed (TCRCD/ NRCS, 1998). The efficiency of bedload retention was estimated to be 70 to 80 percent, and have greatly reduced the volume of fine sediment entering the mainstem Trinity River. Unfortunately, the storage capacity of these ponds has been exceeded during a single storm event (e.g., in January 1995), which allows substantial coarse sand to enter the mainstem before the ponds can be dredged. Dredging is expected to continue in the Hamilton sediment ponds to maintain their effectiveness as sediment traps.

4.4.2.2 Riffle Cleaning

Several riffle sites in the Trinity River were mechanically manipulated by "gravel ripping" to reduce the volume of fine sediment in spawning gravels. In summer 1986, a crawler tractor equipped with rip bars was used to break up cemented gravels and dislodge fine sand from the substrate. The riffle cleaning was not completely successful. The lowered flow releases that allowed the tractor to operate within the channel were incapable of transporting large volumes of sand from the study reach. Gravel ripping did bring larger gravel and cobbles to the surface, thus reducing the percentage of surficial sand. However, the dislodged fine sediment was only redistributed a short distance downstream; the total volume of fine sediment in the targeted channel reach remained unchanged (USFWS, 1987). If larger releases had followed the gravel ripping procedures, the fine sediment may have been transported from the study reach and habitat improvement may have been greater.

4.4.2.3 Mainstem Pool Dredging

Thirteen mainstem pools (Table 4.7) have been periodically dredged to reduce fine sediment storage. The primary advantage of pool dredging has been the removal of fine sediment without additional flow releases. However, this technique has limitations. Mainstem pool dredging removes all sediment, including gravels and cobbles. Dredged pools also inhibit the recruitment of upstream bedload to downstream reaches. Although dredging does reduce the total amount of fine sediments, these benefits have not been achieved riverwide because of accessibility problems. Another drawback is that pool dredging increases water turbidity and can disrupt spring chinook salmon holding in the Trinity River in the summer.

4.4.2.4 Side Channel Construction

Natural and artificially constructed side channels have provided valuable low-velocity spawning, rearing, and wintering habitat for juvenile salmon and steelhead (USFWS, 1986, 1987, 1988; Krakker, 1991; Macedo, 1992; Glase, 1994b), as well as appropriate habitat for yellow-legged frogs and juvenile western pond turtles (Lind et al., 1996). From 1988 to 1994, 18 side channels (7 downstream from Douglas City (RM 91.0)) (Appendix G, Plate 2) were constructed pursuant to the Trinity River Restoration Program's goals to improve rearing and spawning habitat. Side channels were constructed on pre-TRD gravel bars on the inside bends of river meanders and in straight reaches.

Once constructed, these side channels were expected to be maintained by periodic scour from high flows. However, the seven side channels downstream from Douglas City required significant maintenance because their inlets often aggraded (Hampton, 1992). Because of much lower sediment loading, only 1 of the 11 side channels above Douglas City (the site just downstream from the Rush Creek confluence) has required substantial maintenance.

4.4.2.5 Pilot Bank-Rehabilitation Projects

Monitoring suggested that the gently sloping channel margins of the pre-TRD channel, a contemporary morphological feature almost missing upstream from the North Fork Trinity River confluence, were important habitat for salmonid fry (USFWS, 1994). To provide fry habitat, a pilot project to mechanically rehabilitate portions of the mainstem channel was conducted. Nine bank rehabilitation projects, spanning WY1991 to WY1993, were constructed by Reclamation and the Service (Appendix G).

Bank-rehabilitation projects were constructed along straight channel reaches and bends of river meanders (Appendix G, Plate 1). Project sites ranged from 395 to 1,200 feet long. Heavy equipment removed the riparian berm down to the historical cobble surface along one

Table 4.7. Location, name, and date last dredged of pools in the mainstem Trinity River.

Name	River Mile	Date	Name	River Mile	Date
New Bridge	111	1985	SP Pool	103.5	1987
Old Bridge	110	1985	Ponderosa	103.4	1987
Upper Cemetery	109.3	1989	Tom Lang	102.9	1991
Cemetery	109.2	1989	Reo Stott	102	1991
Rush Creek	107	1980	Society	101.5	1990
Bucktail	105	1989	Montana	101	1991
Wellock	104	1984			

bank. The opposite bank remained undisturbed. Since construction, these sites have been monitored and evaluated (Sections 5.2 and 5.4)

4.5 What Has a Historical Perspective Taught Us?

Despite an urgency to restore salmonid populations, single-species management in the Trinity River has not succeeded. The single-species management approach has ignored basic ecosystem functions and has valued river ecosystem integrity as a secondary benefit, rather than the primary contributor, to productive salmon populations.

4.6 The Mainstem Trinity River As It Is

Substantial environmental changes resulting from TRD construction and operation are significantly degrading anadromous salmonid habitat and the river ecosystem. This impact might have been reduced had it been possible to construct the dam without degrading the channel downstream. That was not the case, however. Recent declines in salmon populations may not exist entirely as a consequence of the degradation or loss of habitat, but if fish populations are to be restored and maintained, mainstem habitat quality and quantity must be improved. Rehabilitation will demand no easy and simple cure.

> To date, restoration efforts have focused on slight modifications to baseflows and mechanical restoration approaches, most of which have been ineffective in increasing natural salmon production in the Trinity River.

The mainstem rebounded from human-induced changes during the gold-rush era, but the TRD eliminated or too powerfully altered the two basic ingredients it needed to stay resilient: flow and sediment. Morphologic change was inevitable. The morphologic adjustment to the new, imposed flow and sediment regimes was most dramatic from Lewiston Dam downstream to Douglas City, particularly in the alluvial channel reaches. Fortunately, the mainstem is graced with many significant tributaries, especially the high concentration of tributaries near Douglas City - including Indian, Weaver, Reading, and Browns Creeks. The cumulative contribution of unregulated flows and sediment by these and other tributaries greatly mitigated, but could not prevent, dam-related impacts. A riparian berm is obvious downstream to the North Fork Trinity River confluence, and it might have extended farther if the mainstem did not enter a narrow canyon.

From Lewiston Dam downstream to the North Fork Trinity River confluence, the mainstem narrowed, ceased to migrate, lost its macro-alluvial features, abandoned floodplains, reduced its meander wavelength, had tributary deltas aggrade, and assumed a trapezoidal channel shape. Early successional woody riparian communities, with many of their mortality agents now missing, accelerated morphologic changes by encroaching into the former actively scoured channel. Dense colonization made the banks virtually non-erodible and quickly fossilized alternate bars. Alluvial reaches became rigid within 10 to 15 years.

All spawning and juvenile rearing that once occurred in the mainstem and its tributaries upstream from Lewiston were shifted downstream. The TRFH was built and operated to mitigate for lost habitat upstream from Lewiston. The mainstem channel below Lewiston, which pre-TRD salmon populations had avoided by late-summer, was now home. Hypolimnial dam releases may have cooled water temperatures to an acceptable range for juvenile salmonid rearing, but other native fauna may have been affected. As the mainstem lost its dynamic alluvial nature, this home became less hospitable.

Disruption of the annual pre-TRD flow regimes with their diverse hydrograph components and the loss of coarse sediment supply, both of which were responsible for creating and sustaining the Trinity River ecosystem, caused substantial habitat degradation. Downstream tributaries partially offset the TRD's effects by contributing flow and sediment to the mainstem, but downstream tributaries cannot mitigate the lost snowmelt hydrograph components once generated above Lewiston.

Construction of the TRD resulted in a new ecological role for the mainstem below Lewiston Dam. The mainstem from Lewiston to the North Fork Trinity River confluence must now support spawning and rearing, transport smolts to the ocean, and accommodate upstream migrating adults of several species and stocks. Before the TRD, this was accomplished over a much broader and more diverse geographic area. Can a management philosophy with an ecosystem perspective, rather than the past single-species management philosophy, make this imposed ecological role a reality?

4.7 Toward a Restoration Philosophy

Fluvial geomorphic processes underpin the structure and function of alluvial river ecosystems; this must have been the case for the Trinity River ecosystem. As interactions between a river's physical and biological components increase geometrically, even simple cause-and-effect relationships become obscured: teasing out isolated causes or effects becomes a study in contingencies. The most effective strategy for rehabilitating habitat and fully realizing the potential productivity of an anadromous salmonid fishery is a top-down approach: the restoration of river system integrity. Anadromous fish in the Trinity River evolved in a dynamic, mixed alluvial river system that has since become static. If naturally producing salmonid populations are to be restored, habitats on which these populations historically depended must be provided to the greatest extent possible, by rejuvenating the necessary geomorphic and ecological processes within contemporary sediment and flow constraints.

Restoring the Trinity River to pre-TRD conditions cannot occur barring significant reconfiguring or removal of the TRD. Likewise, continuing existing management will not significantly improve habitat and salmonid productivity. The optimal solution is to restore a Trinity River smaller in scale than the pre-TRD river,but that possesses the fluvial processes and channel morphology of the pre-TRD channel.

Total restoration of the pre-TRD channel morphology is not the goal: as long as the TRD operates, the historical channel dimensions cannot be recreated because not all physical processes can be restored to pre-TRD levels. The former huge winter floods will never happen again, and the dams will continue to trap all coarse bedload. Instead, a different mainstem will be targeted, an approximation of the pre-TRD mixed alluvial channel, although smaller in scale than the pre-TRD river. If an alluvial river system can be restored, the structural components of anadromous fish habitat will reappear.

Creating a dynamic alternate bar channel form and maintaining its habitat characteristics will be critical in this effort, but rehabilitating the physical habitat is only part of the challenge. Water quality needs, particularly summer water temperatures, also must be addressed. This will mean creating an environment that did not exist prior to the TRD.

4.8 Attributes of Alluvial River Ecosystems

To develop the goals and objectives for rehabilitating the Trinity River, attributes of an alluvial riverine system are identified, as well as the physical processes necessary to sustain each attribute (Appendix H). The attributes were derived from studies of the Trinity River (McBain and Trush, 1997) and published research on alluvial rivers. These attributes were used to assess mainstem river integrity and select/prioritize the appropriate restoration strategies presented in this report.

Pristine, unregulated rivers with morphologies comparable to the Trinity River no longer exist regionally, making within-basin comparisons between regulated and unregulated river systems impossible. Instead, it was necessary to associate general fluvial geomorphic processes with contemporary annual flow regimes in unregulated river systems outside the region. The mainstem Trinity River below Lewiston has no reasonable unregulated counterpart to serve as a model, so these attributes were developed from historical streamflow records, cross sections, aerial photographs, and local and scientific literature review. Development of these attributes largely circumvented the common shortcoming of having insufficient pre-regulation data regarding channel morphology, pre-TRD channel dynamics, and associated anadromous salmonid production.

The following attributes target specific distinguishing physical and biological processes in coarse gravel-bedded alluvial rivers such as the Trinity River mainstem:

ATTRIBUTE No. 1. Spatially complex channel morphology.

No single segment of channelbed provides habitat for all species, but the sum of channel segments provides high-quality habitat for native species. A wide range of structurally complex physical environments supports diverse and productive biological communities;

ATTRIBUTE No. 2. Flows and water quality are predictably variable.

Inter-annual and seasonal flow regimes are broadly predictable, but specific flow magnitudes, timing, durations, and frequencies are unpredictable because of runoff patterns produced by storms and droughts. Seasonal water-quality characteristics, especially water temperature, turbidity, and suspended-sediment concentration, are similar to those of regional unregulated rivers and fluctuate seasonally. This temporal "predictable unpredictability" is a foundation of river ecosystem integrity;

ATTRIBUTE No. 3. Frequently mobilized channelbed surface.

Channelbed framework particles of coarse alluvial surfaces are mobilized by the bankfull discharge, which on average occurs every 1 to 2 years;

ATTRIBUTE No. 4. Periodic channelbed scour and fill.

Alternate bars are scoured deeper than their coarse surface layers by floods exceeding 3- to 5-year annual maximum flood recurrences. This scour is typically accompanied by re-deposition, such that net change in channelbed topography following a scouring flood usually is minimal;

ATTRIBUTE No. 5. Balanced fine and coarse sediment budgets.

River reaches export fine and coarse sediment at rates approximately equal to sediment inputs. The amount and mode of sediment storage within a given river reach fluctuates, but sustains channel morphology in dynamic quasi-equilibrium when averaged over many years. A balanced coarse sediment budget implies bedload continuity: most particle sizes of the channelbed must be transported through the river reach;

ATTRIBUTE No. 6. Periodic channel migration or avulsion.

The channel migrates or avulses at variable rates and establishes meander wavelengths consistent with those of regional rivers with similar flow regimes, valley slopes, confinement, sediment supply, and sediment caliber;

ATTRIBUTE No. 7. A functional floodplain.

On average, floodplains are inundated once annually by high flows equaling or exceeding bankfull stage. Lower terraces are inundated by less frequent floods, with their expected inundation frequencies dependent on norms exhibited by similar, but unregulated river channels. These floods also deposit finer sediment onto the floodplain and low terraces;

ATTRIBUTE No. 8. Infrequent channel-resetting floods.

Single large floods (e.g., exceeding 10- to 20-year recurrences) cause channel avulsions, rejuvenation of mature riparian stands to early-successional stages, side channel formation and maintenance, and creation of off-channel wetlands (e.g., oxbows). Resetting floods are as critical for creating and maintaining channel complexity as are lesser magnitude floods;

ATTRIBUTE No. 9. Self-sustaining diverse riparian plant communities.

Natural woody riparian plant establishment and mortality, based on species life-history strategies, culminate in early- and late-successional stand structures and species diversities (canopy and understory) characteristic of self-sustaining riparian communities common to regional unregulated river corridors;

ATTRIBUTE No. 10. Naturally fluctuating groundwater table.

Inter-annual and seasonal groundwater fluctuations in floodplains, terraces, sloughs, and adjacent wetlands are similar to those of regional unregulated river corridors.

Attributes No. 1, 2, 5, and 10 can help diagnose river ecosystem integrity. Attribute No. 2, central to all physical and ecological processes, is repeatedly addressed in the other attributes. But the need to emphasize annual flow variation warranted a separate attribute. Excepting

Restoring the Trinity River requires quantitative objectives. Ten fundamental attributes of alluvial river integrity were developed to provide these quantitative objectives.

Attribute No. 2, these attributes are direct consequences of fluvial geomorphic processes comprising other attributes. Their usefulness is derived from regional and (or) historical expectations of runoff patterns, channel morphology, and riparian community structure in unregulated river ecosystems with minimally disturbed watersheds. All help define a desired condition and quantify channel rehabilitation goals.

Attributes No. 3, 4, 6, 7, 8, and 9 are process-oriented and can be departure points (in most cases, initial hypotheses) for investigating important physical and biological processes. These attributes also served as our restoration goals and lead to adaptive management monitoring objectives. Many attributes are interrelated. For example, maintaining an alternate bar morphology (No. 3 and No. 4) strongly affects channel migration and avulsion (No. 6), floodplain formation (No. 7), and woody riparian establishment (No. 9).

To maintain the channel processes that provide high-quality instream and riparian habitats described in these attributes, flow recommendations must link two flows: those that provide suitable seasonal habitat and those that create and maintain the structural framework and spatial complexity that is the foundation of the micro-habitats. No single flow can provide sufficient habitat for all life stages and species of salmonids that existed prior to construction of the TRD; rather, a varied regime of flows is required to restore and maintain the overall health and productivity of this alluvial river, and thus restore and maintain the fishery resources of the Trinity River.

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